UNIVERSITY OF NAIROBI

School of Engineering

Department of Geospatial and Space Technology

APPLICATION OF GIS TECHNOLOGY IN URBAN LAND USE PLANNING

Case Study of Kimende Town, Kiambu County.

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A project report submitted in partial fulfillment of the requirement for the degree of *Master of Science in Geographical Information Systems (GIS)* in the Department of Geospatial and Space Technology in The University of Nairobi.

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ABSTRACT

Application of GIS in urban land use planning project intends to explore various ways in which geospatial technologies can be employed for effective land use planning in towns and cities. This is a case study of Kimende town, Lari Subcounty in Kiambu County.

The study identified, collected and consolidated all data relating to Kimende. The data was subjected to assessment, preparation, analysis and processing in a bid to obtain the intended deliverables. The resulting deliverables were a base map of Kimende town, a proposed land use map and a geodatabase of the study area containing all the relevant data. Further to that the results indicated sprawl of development beyond the township limit as well as deficits of various land uses in the town.

In conclusion the importance of employing GIS in any plan preparation was manifested through processes such as but not limited to spatial analysis, querying, visualization and modeling are achievable as they are paramount in preparation of a development plan which ends up solving pertinent planning issues.

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Chapter 1: INTRODUCTION

This chapter deals with the background of the study, statement of the problem and justification of the study. It also looked at the research objectives, research questions.

1.1 Background

Land use planning is a process that aims at mitigating the negative effects of land use and enhancing the efficient use of resources The main objective of this, is allocating land use to meet the needs of people while safeguarding future resources.

Towns lack comprehensive development plans for guiding the location of developments and provision of infrastructure such as car parks, access roads, toilets, drainage and sewerage just to mention a few. Traditionally land use plans have been prepared by planners but in a manual form which poses a lot of Shortcomings when certain analysis have to be conducted for purposes of decision making. Some of these challenges include: requirement of a huge storage space; difficulty in updating manual maps and a long tedious processes of tracing data. This can be eased by developing a geodatabase that will not only store information but will have additional functionality to help a planner in their daily operations.

Kiambu County is an immediate neighbor to the capital city of Kenya Nairobi, hence plays an important function as a bedroom town to Nairobi and neighboring towns and counties.A lot of developments have come up in the last five years which have seen a huge population rise of people residing in Kiambu. Currently it has an urban population of 1,010,991 persons (County Government of Kiambu, 2013). This means we have to plan for this population in time before slums begin proliferating and straining of the existing infrastructures such as water, sewer, electricity, education, commercial, public purpose, recreational and industrial facilities. All these have to be well planned so as to achieve ultimate compatibility and smart towns worth living in.

Kiambu county is one of the counties that have embraced modern information technology such as Geographic Information System (GIS) and made a step to procure and implement a GIS system,(Mutua & Mwaniki, 2017) hence this is one of the motivating factors to carry out a study in Kimende town found within Kiambu county . However, one of the evident shortcomings is that despite the system being in place its capabilities are not fully exploited for the purposes of physical planning.

In Kenya, (National Council for Law Reporting, 2012) and urban areas and cities act (KLR, 2017) has recognized the importance of inclusion of GIS in physical planning. Section 105 (f) of the County Government Act stipulates that a county planning unit shall ensure the establishment of a GIS based database system. (National Council for Law Reporting, 2012)

In addition to the above section 110 of the county government act outlines that there shall be a ten year county GIS based database system spatial plan for each county, which shall be a component part of the county integrated development plan providing a spatial depiction of the social and economic development programme of the county as articulated in the integrated county development plan; clear statements of how the spatial plan is linked to the regional, national and other county plans; and clear clarifications on the anticipated sustainable development outcomes of the spatial plan. (National Council for Law Reporting, 2012)and (KLR, 2017)

In order to realize the above mandate, existing data requires a lot of reorganization and proper management so as to avoid data redundancy, loss of resources such as time and money. Hence, it's important for towns to have up to date geodatabases which have more advantages compared to the traditional methods of storing and map preparation. Hence this study was aimed at demonstrating how GIS capabilities and functionalities could be exploited to ease urban land use planning.

1.2 Problem Statement

At the time of the study, Kimende town lacked a land use plan to guide development. There only

exists a hardcopy township plan prepared in 1975. It shows the demarcated town plots and just a few land uses This therefore failed to guide growth direction and trends of the rising populace of Kimende town.

Again, analogue maps come with their own share of disadvantages such as being static hence limiting modification when updates and changes are required. All features cannot as well be represented at the same time due to limitations of drawing using one single scale. They also tend to be limited to covering certain area which limits integration with other plans prepared at all other levels say county plans and national plans. In addition to the above shortcomings they require a huge physical storage space which automatically subjects them to wear and tear with time. All the above make hardcopy maps coarse for use in urban planning purposes hence limit their level of usefulness. . In a nutshell, the absence an interactive Geo database containing up to date data, hinders a smooth transition from old ways of plan preparation and poor data management practices to flexible and efficient plan preparations and data management.

Therefore, this study was focused on building a geodatabase using existing planning information of Kimende to generate its digital base map, a proposed land use plan and thereafter do a comparison.

1.3:Study Objectives

1.3.1: Main objective

To develop an interactive geodatabase for facilitating land use planning of Kimende Town.

1.3.2: Specific objectives

1. To prepare a base map for the study area.
2. To prepare a proposed development plan for the study area.
3. To compare the proposed land use plan of Kimende town alongside the existing planning

standards.

1.4 Justification of the study

This study was aimed at designing a geodatabase that would hold all the datasets required in preparation of any development plan and other thematic maps required in planning. All of which make it easier to prepare and update existing plans as data is readily available in the geodatabase.

In addition, it aimed at producing a functional physical development plan that would be available both in digital and hard copy form to guide upcoming development.. An up to date township plan that is in line with the needs of its populace is very paramount. Hence a plan prepared in 1975 does not match the needs of the year 2019 hence the drive to prepare another. This would not only help the county government of Kiambu in development control and urban land use management but also the residents of Kimende town.

This plan showed how GIS can be inculcated in planning to make it better and more responsive in tackling planning issues. With availability of adequate capacity and allocation of finances it can be duplicated in other towns, Counties as County spatial plan, and at National level as national spatial plan all anchored on GIS.

1.5: Scope of Work

This study was intended to demonstrate the applications of GIS in land use planning. The study area covered part delineated area of Kimende town, Lari subcounty in Kiambu county. This study was conducted in five phases that include desktop review, reconnaissance, fieldwork, data analysis, data processing, and data presentation. The expected outcome was a current base maps, a proposed land use plan and a geodatabase which acts as a repository for all planning work and aiding in base map preparation.

1.6 Considerations Taken in this Project

The area covered was not big enough to incorporate all the zones, only a few of them are properly illustrated in this project. The study area is a vibrant town along that A104 Road, which is rapidly growing with land uses from agriculture to other land use forms mainly commercial and residential. This mainly occurs without prior means to guide it. This is attributed by several reasons such as

a) Absence of an up to date development plan for Kimende town.
b) Poor surveying practices where surveyors provide roads of 6M all over the town without considering planning standards and guidelines.

1.7 Organization of the Report

This report consists of 5 chapters. The first chapter contains general introduction of the study problem and a brief outline of the expected deliverables; Chapter two looks into the literature review which discusses similar subjects related to the problem of discussion: Chapter 3 outlines the methodology employed in attaining the results. Chapter four looks into the results and findings attained by the project and discussion of the same. Lastly, chapter five has the Conclusions and Recommendations.

Chapter 2: Literature Review

2.0 Introduction

This chapter reviewed relevant literature information that was related and consistent with the objectives of the study. Important issues and practical problems were brought out and critically examined so as to determine the current facts. This section was very paramount as it determined the information that links the current study with past studies and what future studies need to explore so as to improve knowledge.

2.1 Definition of GIS Technology

According to (Star & Estes, 1990) GIS is an information system, designed to work with data referenced by spatial or geographic coordinates. In other words, it's both a database system with specific capabilities for spatially-referenced data, as well as a set of operations for working with the data.

Later on, (Iyengar, 1998), conquered with an earlier definition and further alluded that GIS is a system of hardware, software, and procedures designed to support capture, management, manipulation, analysis, modeling and the final display of spatially-referenced data for solving complex planning and management problems.

The Main purpose of GIS lies in formation of knowledge base of the Earth, its territories, landscape and timely delivery of sufficient and accurate geodata to GIS users to increase their working efficiency. (Development and creating of GIS, 2012).

2.2 Land use

According to handbook after reconstructing natural disasters: Safer homes and stronger Communities, Land use refers to a geographical concept in which parcels of land are utilized by people and society. Land use planning is an activity that examines the factors that influence the nature

and dynamics of land usage and develops ways to optimize those variables to achieve larger social, economic, and ecological benefits.(Phelps et al, 2010).

2.3 Land use planning

Land use planning has previously been defined as a public policy exercise that designates and regulates the use of land in order to improve a society's physical, economic, and social efficiency and well-being. By considering socioeconomic trends as well as physical and geographical features (such as topography and ecology), planning helps identify the preferred land uses that will support local development goals. The final outcome is allocation and zoning of land for specific uses, regulation of the intensity of use, and formulation of legal and administrative instruments that support the plan. A land use plan may be prepared for an urban area, a rural area, or a region encompassing both urban and rural areas. (FAO-UN, 1993b).

2.4 What is urban land use planning

According to UN Habitat, Urban planning is a design exercise that uses the land use plan as a framework to propose the optimal physical infrastructure for a settlement or area, including infrastructure for public services, transport, economic activities, recreation, and environmental protection. A physical plan may be prepared for an urban area or a rural area. A physical plan for an urban region can have both rural and urban components, although the latter usually predominates. A physical plan at a regional scale can also deal with the provision of specific regional infrastructure, such as a regional road or a bulk water supply system.(UN Habitat, 2011).

2.5 Urban Land use Planning Principles

2.5.1 Adequate space for streets and an efficient street network

According to the five principles of sustainable neighborhood planning streets are the most important public spaces where people meet and interact daily. It's a structural form that shapes the urban form and influences patterns of development of blocks, streets, buildings, open spaces and landscapes.

Good ample spaces contribute to improved connectivity which in turn allows for economic development. As efficient connectivity increases travel distances reduce while routes options increase as well as modes of travels. This eventually allows for more direct travels between destinations which creates a more accessible and resilient system. This therefore reduces on time, money and resources.(UN Habitat 2014).

2.5.2 Mixed land use and limited land-use specialization

Mixed land use is another principle discussed by UN habitat under the 5 principles of sustainable neighborhood planning. It's where a range of compatible uses, functions and roles are combined in a building structure, block or neighborhood hence reducing demand for commuter travels to and from work to homes. Guideline stipulates that at least 40% of total floor space should be allocated for economic use both on the city and neighborhood level plans and designs. It also recommends on minimizing single function blocks to not more than 10% of total land use(UN Habitat 2014).

2.5.3 Social mix

This third principle looked at how social classes in a community interact freely hence promoting accessibility to equitable urban opportunities for instance by providing different types of housing.it highly promotes healthy interactions and networks which are the key driving forces to any town or city life. The essence of the above principle was to avoid exclusion of members of a society. Under this residential space should be reserved for affordable housing. (UN Habitat 2014).

2.5.4 Adequate and well-designed density

This principle suggested that high-density areas in towns and cities can accommodates high populations growth and ensure available land is used efficiently as per oncoming demand. A good planned densification strategy in a highly density area or zone significantly minimizes the cost of providing key urban services such as urban infrastructure.eg water and waste provision services. UN-Habitat's density principle proposed at least 15,000 people/km². (UN Habitat 2014).

2.5.5 Connectivity

Fourth principle touched on connectivity which at a town or city level relates to movements and permeability in an area. A proper design promotes walking and use of multiple modes of transport in a town. Streets and buildings should be well connected to always avoid dark and unsafe walkways. This therefore makes streets attractive and user friendly to all people in the society.it also allows for use of non-motorized modes of transport and in the long run reduce over reliance to motorized means such as cars while street activity is promoted(UN Habitat 2014).

2.6 Applications of GIS in urban and regional Planning

The application of GIS in spatial planning spans across all development sectors. Today, GIS is used to perform activities such as;

2.6.1 Land Use Planning

According to a GIS assessment carried out in the counties in 2017, preparation of base maps, real time data collection on land uses and land cover, plan preparation including scenario modeling are some of the key activities undertaken in land use planning. Land use modeling can be presented as maps statistic sand summary tables which help in explanations of change and policy amendments where applicable. Populations projections and estimates are done in GIS to form basis of proposals in plan preparation. (Mutua & Mwaniki, 2017).

2.6.2 Monitoring growth and detecting change in development areas

According to the GIS assessment by Council of Governors, various developments are monitored land uses changes such as urban sprawl and growth are tracked. This is usually paramount in understanding urban rural growth so as to plan accordingly. In addition GIS and remote sensing are a powerful means of monitoring land uses changes at high temporal resolution at a lower cost than there associated with use of traditional method. This helps planners to understand the dynamics of urban/ rural growth and to set forth better and practical development goals. (Mutua & Mwaniki,

2017).This is backed by an early study that showed satellite remote sensing was a potentially powerful means of monitoring land-use change at high temporal resolution and lower costs than those associated with the use of traditional 100 methods(.Raey et al 1995).

2.6.3 Development monitoring, & conducting suitability and feasibility studies.

According to Bandyopadhyay et al land suitability is the ability of a portion of land to tolerate production of crops in a sustainable way. This information on the constraints and opportunities of the land guides decisions on optimal utilization of resources which is very paramount for land use planning. Further to this such a kind of analysis enables decision makers such as land users, land use planners, and agricultural support services to develop a crop management able to overcome such constraints, increasing the productivity .(Bandyopadhyay Et al, 2009)

2.6.4 Applications in land management

Land information management systems were defined as computerized databases models' decisions support tools with an interactive user interface to facilitate access of information according to (FAO-UN, 1993b) .Parcel information can be digitized in GIS and details such as ownership, measurements areas, property tax rates, together with existing, ongoing and approved developments can all be added into a database. In addition, this system monitors development and enhances tax collection.(Mutua & Mwaniki, 2017)

2.6.5 Applications in documentation, development review process, and front counter service.

According to (Mutua & Mwaniki, 2017) in the GIS Assesment Report , development review process ensures that plans for development adhere to existing legal requirements as well as protect citizens from environmental or public safety hazards and support progressive economic development. Many planning agencies are today integrating GIS solutions as a central component in the development application review process, through which submission of development applications and the review process can be tracked.

According to 40th Annual Hawaii International Conference on System Sciences, Information system support for emergency response is an active field of research and development (*Proceedings of the 40th Annual Hawaii International Conference on System Sciences*, 2007). Here spatial data and geographical information systems (GIS) play an important role in helping increase the *situational awareness*. This includes location of incidents, affected areas or buildings, location of rescue teams, victims, shelters, etc. (Snoeren, 2007) , (Zlatanova et al , 2009).

2.6.6 GIS is a tool for Participatory Planning and information dissemination

Participatory GIS was discussed to be an emergent *practice* in its own right; developing out of participatory approaches to planning and spatial information and communication management (Rambaldi & Weiner, 2004). Rambaldi, further alluded that Participatory GIS includes several methods while involving the local population in the mapping process, "integrates several tools and methods, whilst often relying on the combination of expert skills with socially differentiated local knowledge*"*.(Rambaldi, 2005)

2.6.7 Applications in natural resource mapping, and environmental planning.

In developing a natural resource inventory GIS is seen to be very paramount. It aims to show the locations and uses of different resources. This inventory assesses environmental constraints, identification of environmental assets that require protection such as water sources and wetlands and lastly in site selection for uses such as sewer treatment plans. In addition, they are used to model the effects of various activities of the environment that always inform formulation of environmental management plans.(Mutua & Mwaniki, 2017).

2.6.8 Applications in Urban governance

From the assessment carried out on GIS needs in counties in 2017, E-government is using the Internet and GIS to create more effective government. The combination of readily available Internet access and maps lets governments provide a new level of service to both businesses and the public. For

example, GIS-enabled Web sites today provide services such as online mapping, fee payment, and application submission that were not previously available. This is helping to both enhance the ease and efficiency of urban governance.(Mutua & Mwaniki, 2017).

2.7 GIS Capabilities applicable in Planning.

GIS has emerged to be an information system that integrates data from numerous sources so as to provide the information for purposes of efficient decision making in planning(Han & Kim, 1989).In addition, information systems for urban planning include DBMS, Decision support systems (DSS) and Expert Systems. GIS serves as a database and a toolbox for urban planning. Spatial and textual data in database-oriented GIS are linked via Geo relational models. GIS essentially supports data retrieval, query and mapping. Data can be extracted by planners from the databases to be input for modelling and spatial analysis purposes. When all this is combined with data from other tabular databases or specially conducted surveys, geographical information can be used to make effective planning decisions when used as a toolbox it allows for spatial analysis to be carried out via geoprocessing functions like map overlays, connectivity measurements and buffering (Berry, 1987) ,Tomlin, 1990).map overlay comes out to be the most useful tool since planners often use it for suitability analysis mapping which happens to be a very vital component of urban planning. (Hopkins, 1977); (McHarg, 1969);(Steinitz, Et al, 1976).

The diagram below illustrates the relationship that exists in GIS and Urban planning

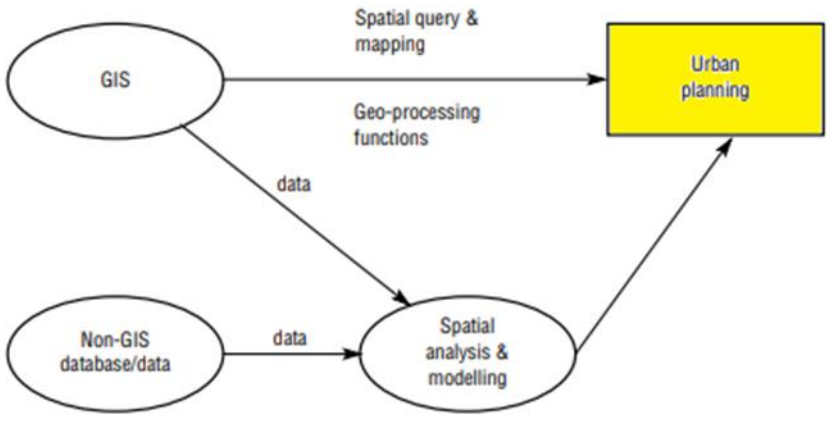

Figure 1: Gis and urban planning relationship.

Source :(Webster, 1994).

As discussed above, Webster and marble also said that Visualization, spatial analysis, database management and modeling are the main ways urban planning employs GIS. (Webster, 1993) (Webster, 1994) ,(D F Marble & Amundson, 1988).

Chapter 3: Research Methodology

3.0 Introduction

Geographic information systems applications in planning, particularly in this project was employed as a value addition tool to the traditional planning methods. A plan was envisioned to guide development and growth in a sustainable manner socially, economically and environmentally. Land uses were aligned in a manner that they are compatible with one another for harmonious existence. Incorporation of GIS in the plan ensured production of a digital plan which was easier to store, update and manipulate data.

This chapter describes the methodology used in this study, various aspects of the study area, data collection tools and procedure, methods employed and analysis carried out. Application of GIS in this project was by using GIS as a value addition tool to the traditional planning methods.

3.1 Study area

Kimende is a town in Lari subcounty, in the North west of Kiambu county. It's located 55km from Nairobi CBD along the Nairobi-Nakuru highway (A104 road). Its locational coordinates are 0° 59' 0" South, 36° 38' 0" East about 1400m above sea level. Lari subcounty had a population of 123 895 people and a density of 280per square kilometer. (Knbs, 2009). Kimende also serves as an administrative headquarters to Lari District and sub county.

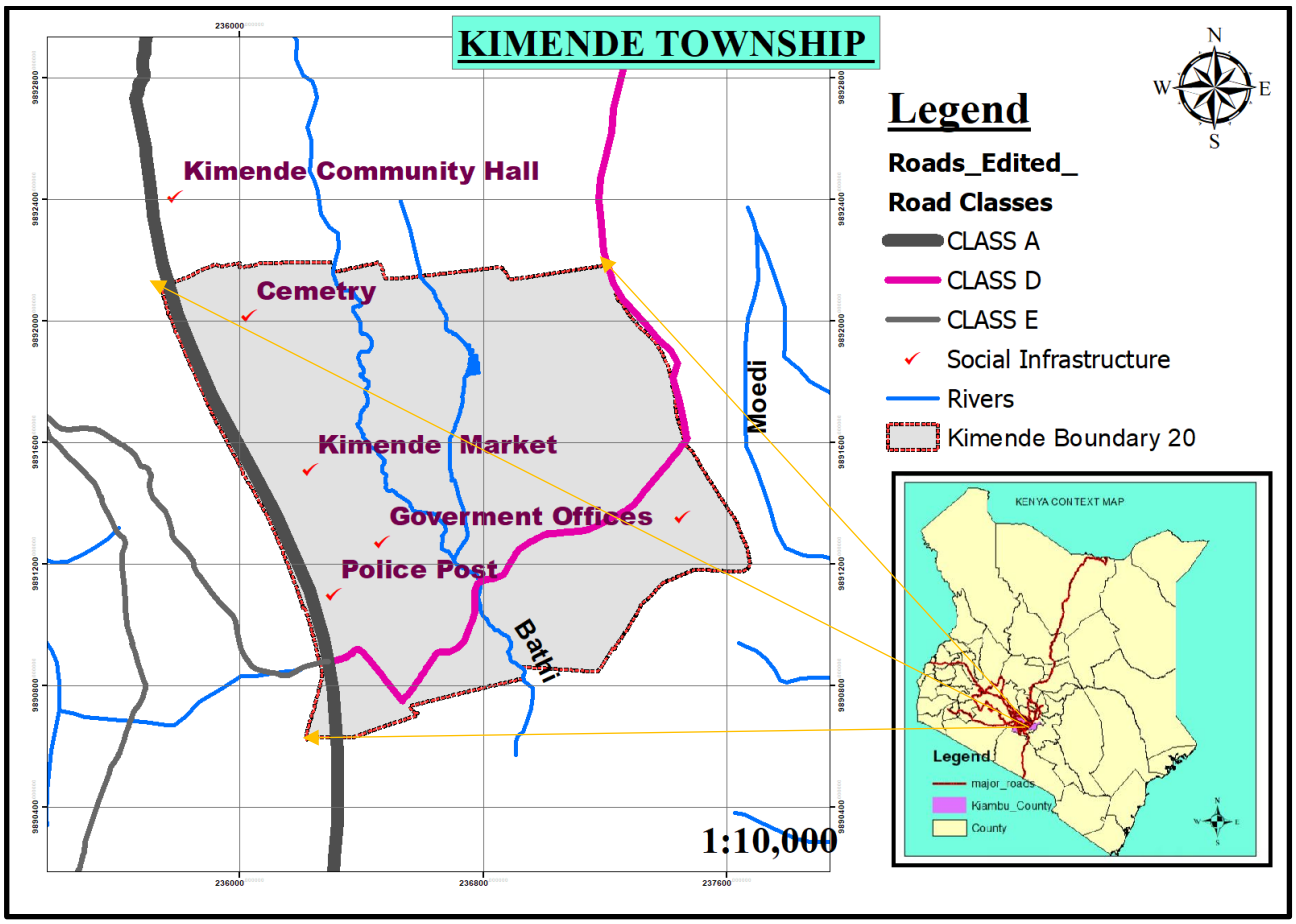

Figure 2: Locational context of the study area.

3.1.1 Land use guide lines as per the physical planning handbook

There are 9 land uses as per the physical planning handbook that are included in the plans as indicated below.

Zone code	Land use	Color code
0	Residential	Brown
1	Industrial	Purple
2	Educational	Yellow
3	Recreational	Green
4	Public Purpose	Orange
5	Commercial	Red

6	Public utility	Blue
7	Transport	Gray
8	Deferred	Not colored
9	Agricultural	Not colored

Table 1: Land use Code and Colors.

Source (*Planning handbook Feb 2008 Revised.doc*, n.d.)

3.2 Factors affecting size determination

3.2.1 Intended land use

Some land uses required larger spaces than others for instance agriculture for it to be viable. Some required being located next to each other for compatibility purposes. A good example of such is a huge area under residential land use attracts other land uses such as education facilities, public purposes such as churches so as to complement the existing population. (Butler et al, 2007).

3.2.2 Available land

Where land sizes were limited, special consideration/priority was given to the main land uses (must have) over other auxiliary (must not have) such as public purpose and recreational facilities.

3.3.3 Location determination

When determining the location of different land uses a number of factors were considered through a suitability analysis. For instance, in locating an industry proximity to the raw materials was key. Location of an industry that emits dangerous products and loud noises near a residential or and educational zone was highly prohibited.

3.3 Tools Employed for the study

A collection of hardware & software was used to complete this project. These are

3.3.1 Hardware

Tool	Make and model	Used for
Laptop	Lenovo idea pad 110	Typing the report Manipulating data in a GIS environment. Data storage
Hard disk	Transend 1 Terabyte	Data storage and backup
GPS	Gps MM20	Collection of GPS coordinates.
Printer	Large format OCE plotter 2024 Kyocera 3232 photocopier and printer HP 1280 A3 printer.	Printing the report. Printing maps. Printing photos.
Digital camera	Huawei Y9	Taking photos of the study area.

Table 2: Equipment used.

3.3.2 Software

Software/application	Version	Used for
Arc GIS	13.0 (1999-2010)	Creation of Geodatabase Map generation Spatial data analysis Storage of spatial data. Georeferencing.

Ms. Word		Word processor for typing the report.
Publisher	12.0.641501000 (2007)	Creating the flow chat
Snip Tool	6.2 (build 9200) 2012	Capturing snap-shots from still screens
GPS	MM20	Collection for collection of coordinates with GPS
Google earth	4.1.7076.4458 (beta) May 6 2007	Obtaining aerial satellite images

Table 3: Software employed.

3.4 Methodology Flow Chart

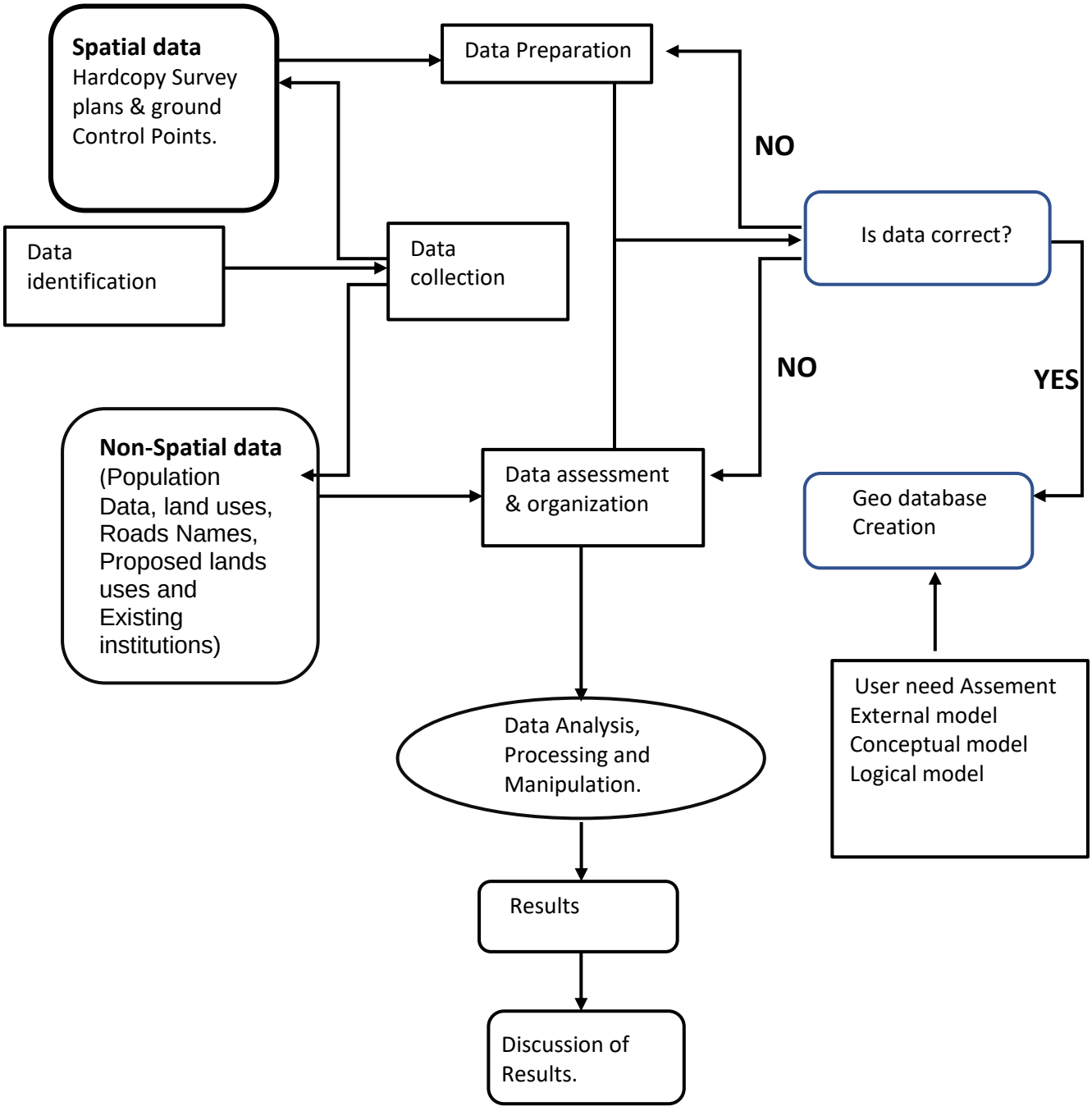

Figure 3: Flow chart showing the methodology.

3.5 Data identification and collection

3.5.1 Spatial data

This is data that has a spatial component to mean that, it was connected to a certain place on the earth's surface. It's also referred to as geospatial or geographical data. It's usually manipulated in a Gis environment to create maps that support decision making(Ormsby et al 2001). In this project the spatial data was obtained from georeferenced survey plan of the township. Ground control points were as well collected using GPS receiver MM20 that had an approximate error of ± 3 M. The ground control points were used to verify the correctness of the georeferenced survey plan as well relate to the adjacent uses. They were further used to georeferenced the google earth image of the study area so as to superimpose the cadastral which was later used to extract some data layers from it.

Point	**Eastings (x)**	**Northings (y)**	**Location description**
1.	236543.58 mE	9890809.24mS	St Peters Catholic Church
2.	236565.05mE	9891082.71mS	Kimende primary School
3.	236252.74mE	9891512.65mS	Market
4.	236494.64mE	9891414.24mS	Control point B
5.	236253.69mE	9891975.02mS	Control point C
6.	236115.06mE	9891857.97mS	Control point D

Table 4: Control Points

3.5.2 Non spatial data

It's also called attribute or characteristic data. This is information that was independent of all geometric considerations. Non spatial data of the town included its name, population, land uses,

roads names, proposed lands uses and existing institutions. Of importance to note is that, this data was not dependent to their location identity. This kind of data was stored in GIS tables having rows and columns where each row shows a spatial feature and each column represents a certain characteristic.

This information was obtained from various sources inform of shapefiles as indicated below.

No.	Data	Source
1.	Roads	Arcgis online KRB
2.	Contours	Ilri website
3.	Rivers	Ilri website
4	Buildings	Mappable
5.	Cadastral boundaries	Survey of Kenya
6.	Land use zones	ACAL Kenya
7.	Railway	Ilri
8.	Forest	Ilri

Table 5: Data and their Sources

3.6 Data assessment

The above datasets were assessed to determine their suitability for use in this assignment so as to meet project objectives. This was realized by determining their spatial representation such as their coordinate systems their scales and resolutions, sources and formats.

3.7 Data preparation

This is the process of assigning a data (raster/vector) to a specific location in relation to earth's coordinate system that is contain a latitude and longitude). The township map was scanned and georeferenced in ARCGIS environment. Data was organized by putting the respective layers and

in appropriate building blocks (points, polylines, polygons) and format georeferencing was done using the following parameters UTM Arc 1960 zone 37 M.

3.8 Data Analysis and processing

3.8.1 Reprojection and transformation

This process was carried out on the datasets collected that exist in other formats so as to register them in one uniform format or coordinate system for interoperability purposes.

3.8.2 Digitization

Digitization of maps containing vital information presented in analogue format was carried out so as to convert raster datasets into vector formats datasets (point, polylines and polygon).

3.8.3 Boundary definition

This involved identification of crucial land uses and developments that exist in Kimende outside the 1975 township boundary. This involved obtaining g a google earth image of the town and mapping out these land uses. It is through this that the boundary of the new township was drawn guided by existing structuring elements on the ground.

3.9 Database design

This is the process of identifying the data that will go into the GIS database and how it will be represented. It involved the following user needs assessment (external modelling), conceptual modelling, logical modelling, and physical design, pilot implementation full implementation and lastly having an operational GIS database. ("ANSI/X3/SPARC Study Group on Data Base Management Systems: (1975), Interim Report. FDT, ACM SIGMOD bulletin. Volume 7, No. 2," 1975).

3.9.1 Requirement Analysis

This is also referred to as user needs assessment, here, determination of finite potential users of

the database, their information needs and hence the data that is required to satisfy those needs. This was carried out by looking at the functions of the planning department and compiling them and identification of data that supports them. Interaction among the functions was also determined to establish how they interact and how data flows in between.

Function approach

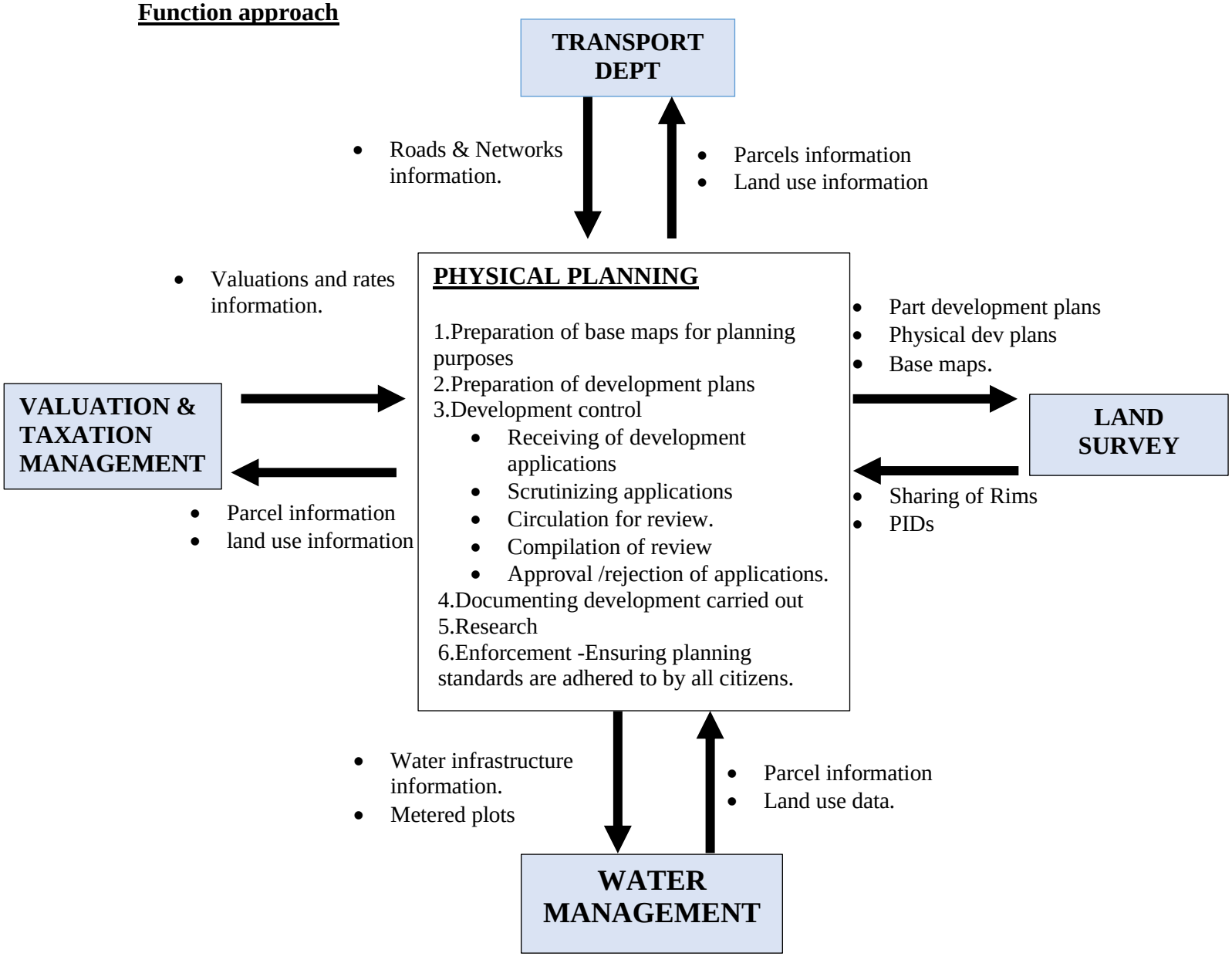

Figure 4: User needs assessment

3.10.2: External model

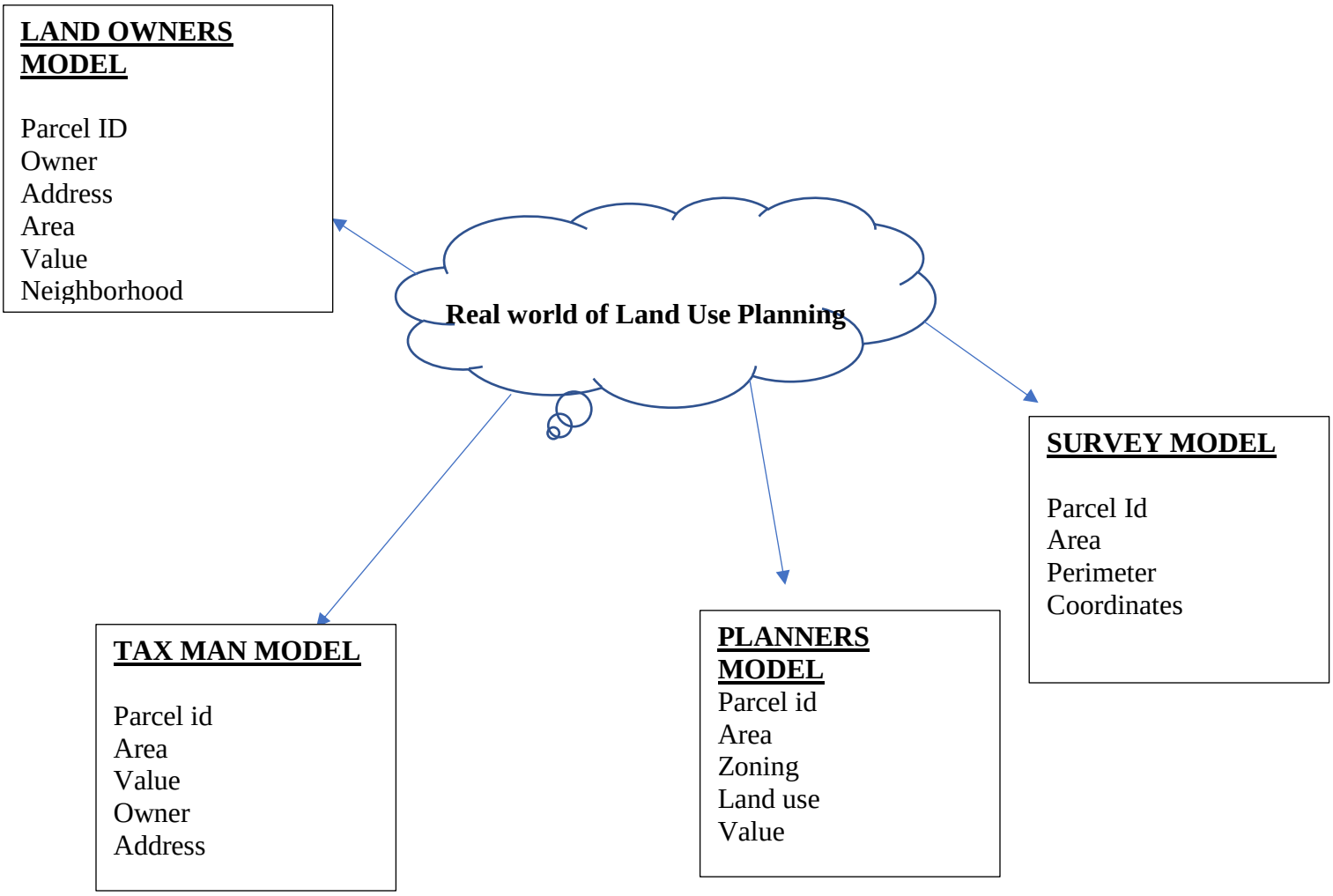

Figure 5: External model.

3.10.3 Conceptual model

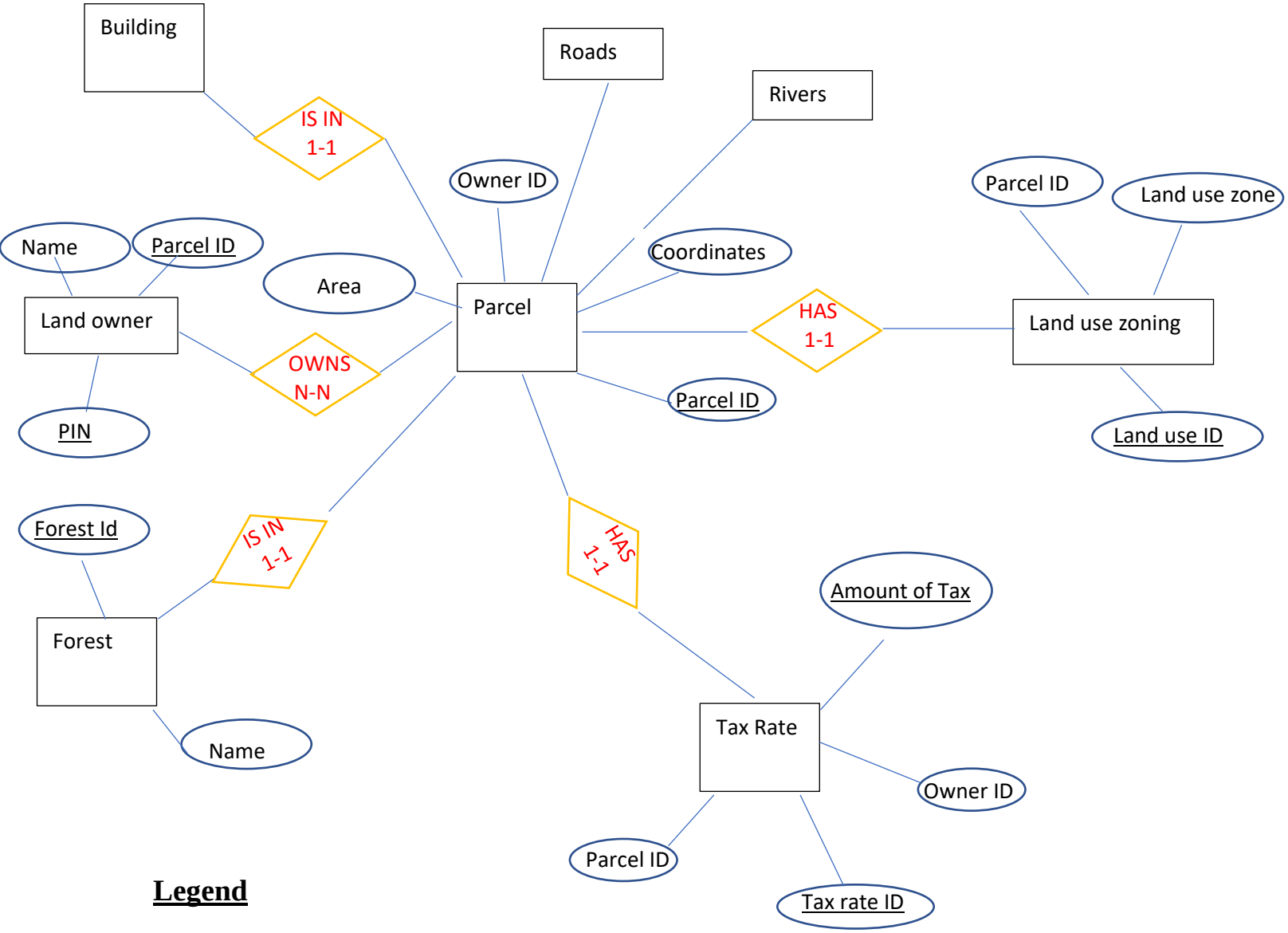

Figure 6: Conceptual Model

3.10.4 Logical Models

- Tax man (Tax ID, Parcel ID, Owner, Rate)
- Surveyor (Parcel ID, area, perimeter, coordinates)
- Planners (Parcel area, land use zoning, land use ID)
- Landowner (Parcel ID ,Name, area, PIN)

3.10.5. Relations

Tax ID,	Parcel ID,	Owner	Rate

Table 6: Tax man Relation

Parcel ID	Area	Name	PIN

Table 7: Land owners Relation

Parcel ID	Area	Perimeter	Coordinates

Table 8: Surveyor's Relation

Area	Land use	Land use ID

Table 9: Planner Relation

Creation of a Geodatabase

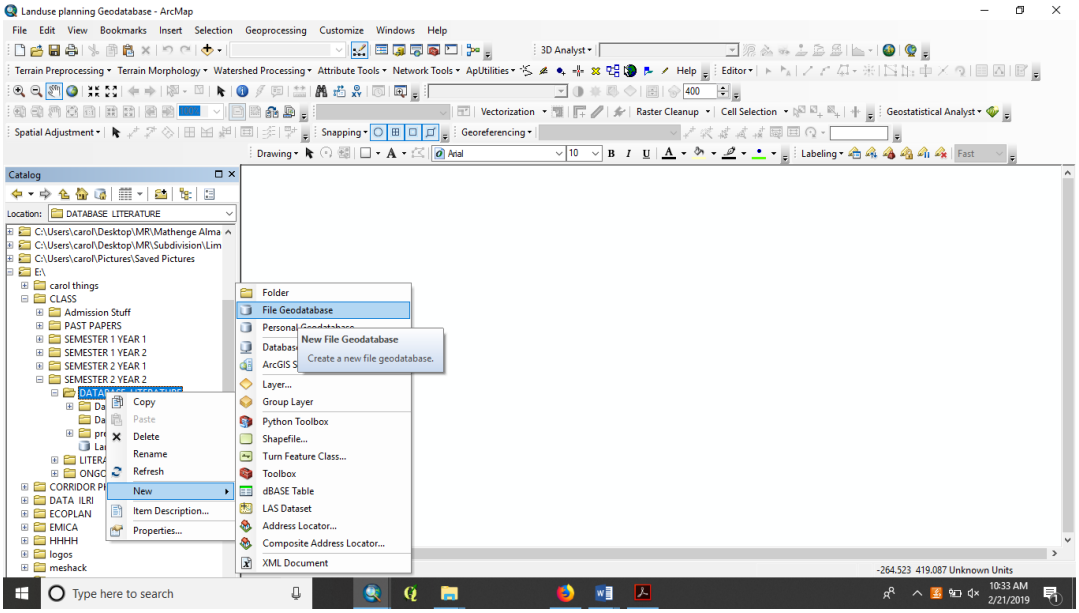

Figure 7: Showing process of geodatabase creation.

In the ARC Catalogue a file geodatabase was created to contain all the data generated for the project.

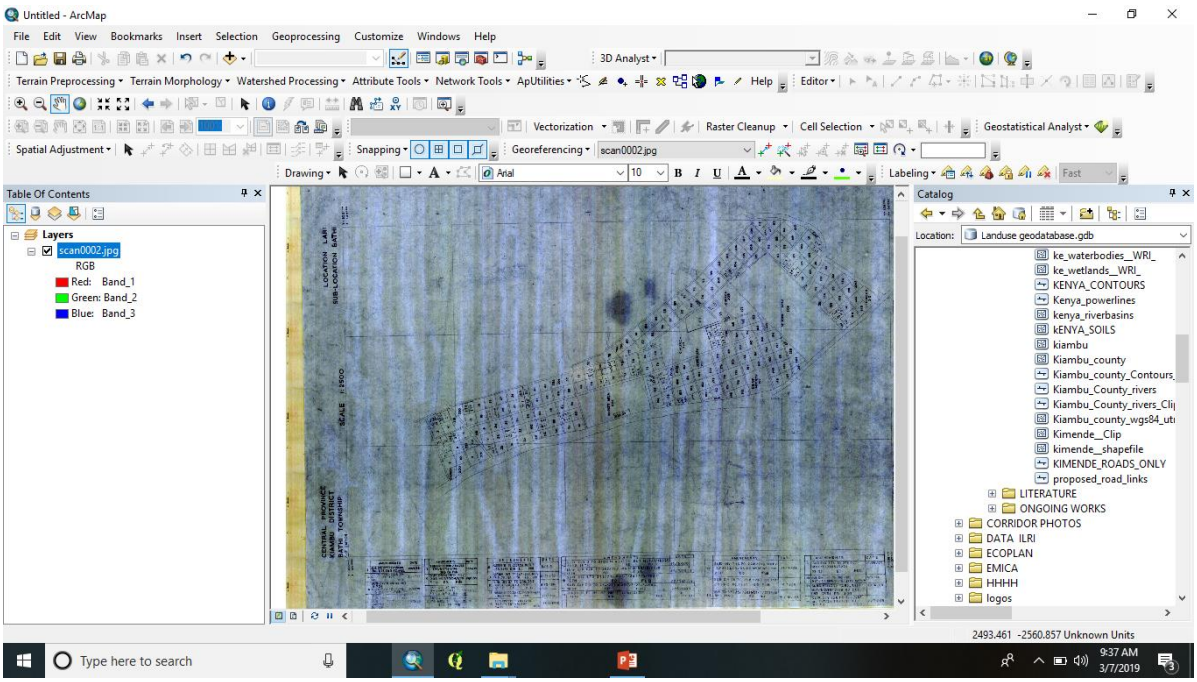

Figure 8: Showing the scanned township map in arcgis environment.

The scanned township area map was loaded onto ARCGIS for georeferencing, and digitization as shown in the next screenshots

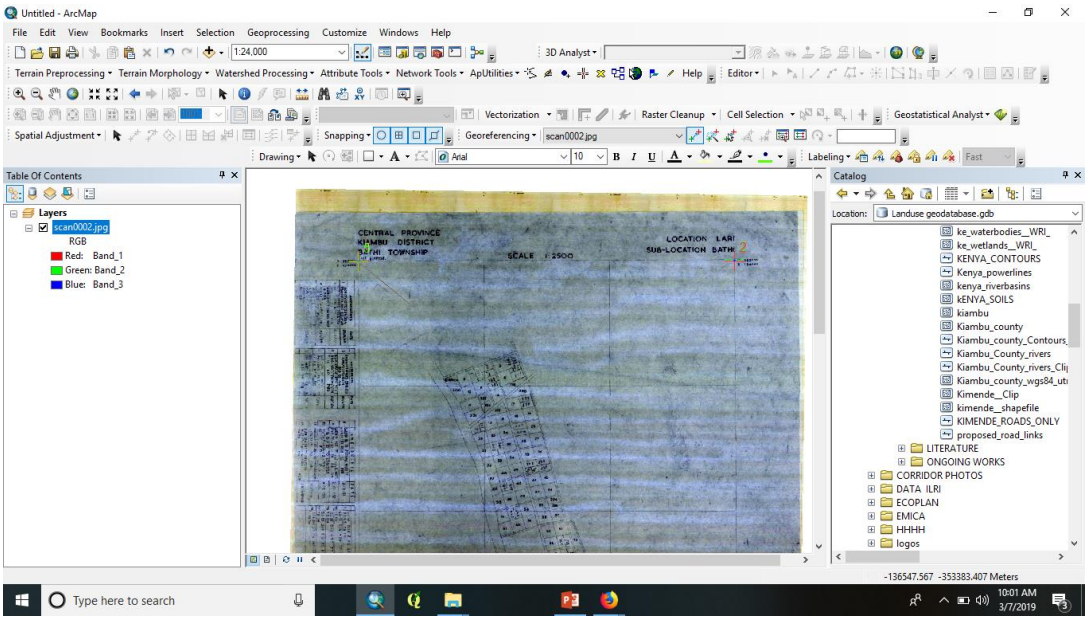

Figure 9: Shows georeferencing of the township map

After properly georeferencing it digitization of the land uses as per the township plan were taken and indicated as attributes.

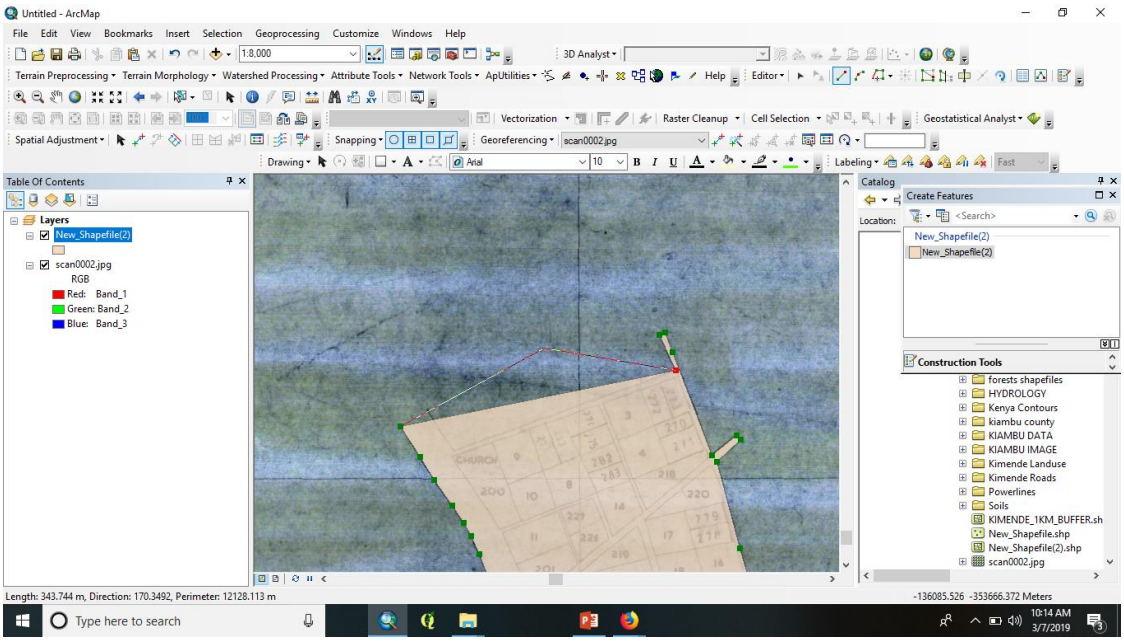

Figure 10: Shows digitization of the township map.

In order to obtain the individual parcels, after digitization of the boundary the cut polygon tool was employed as shown here below.

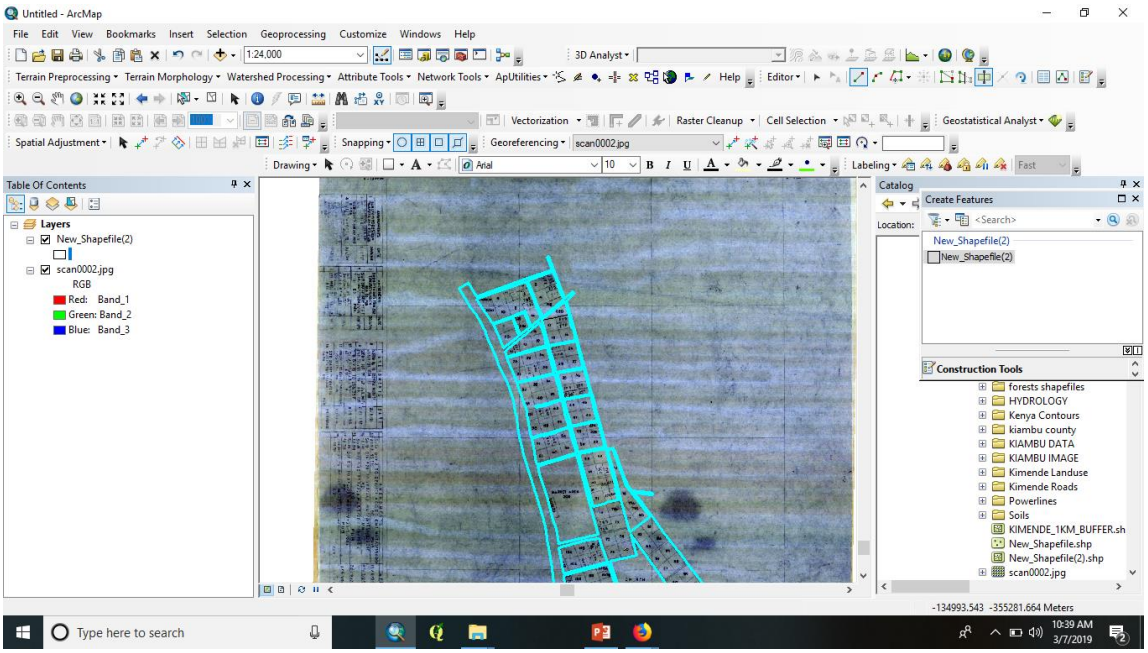

Figure 11: Showing Cutting of polygons

Next was input of attributes of individual plots data (attributes) into the tables

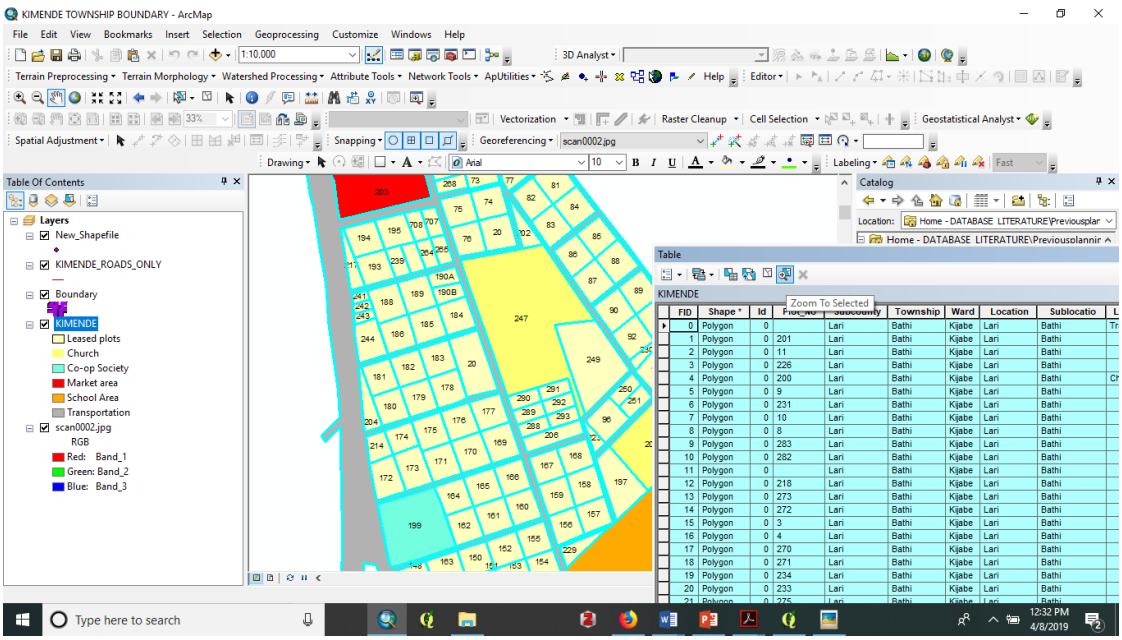

Figure 12: showing non-spatial data in the attribute table.

In addition to the above, data obtained from various sources was imported into the geodatabase as illustrated here below.

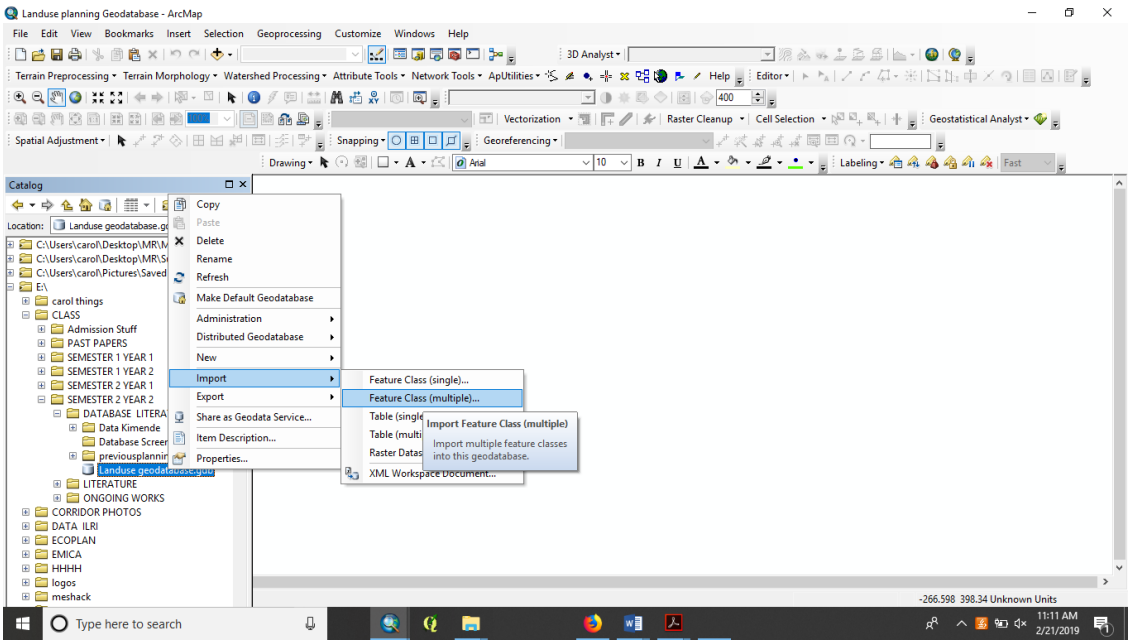

Figure 13: Creation of feature datasets in geodatabase.

The resulting geodatabase with respective feature classes and feature datasets.

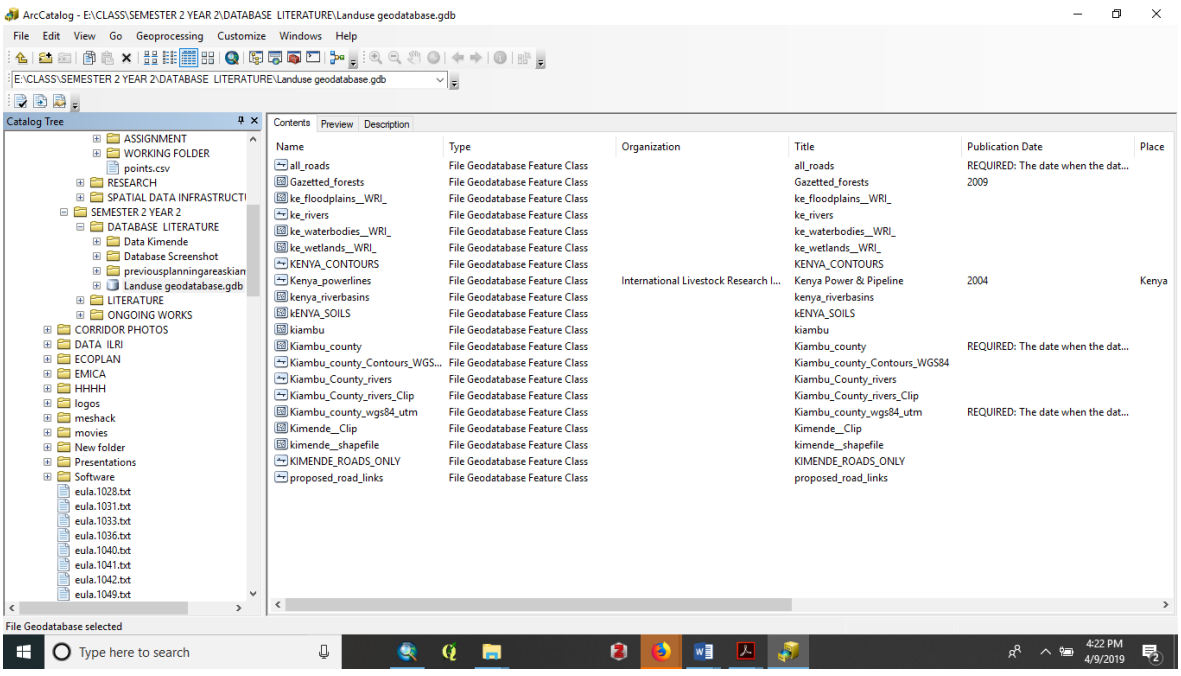

Figure 14: Illustration of loaded datasets in the geodatabase.

Chapter 4: Results and Discussions

In this chapter key finding were presented from the conducted research in Kimende, Bathi township. This research envisioned to create a base map for the township generated from the compiled data in the geodatabase created: to produce a proposed land use map of the Township and lastly compare and contrast the existing and proposed land use.

4.1 Geodatabase

A geodatabase was created where Edited feature dataset and tables were stored in the Land _ use _ planning Geo-database to assist in generating results.

4.1.1 Querying by location

This is search of a point within polygon or a radius search from a specific point. An example is identification of parcels under agricultural land use which are more than 1 acre. This was used to determine areas for allocation of various functions that need larger tracts of land. Again, it's helpful in locating land uses that complement each other. A perfect example from the study was location of schools and residential area.an area designated for educational land use needs to be located within 500- 2000 M walking distance within a residential area

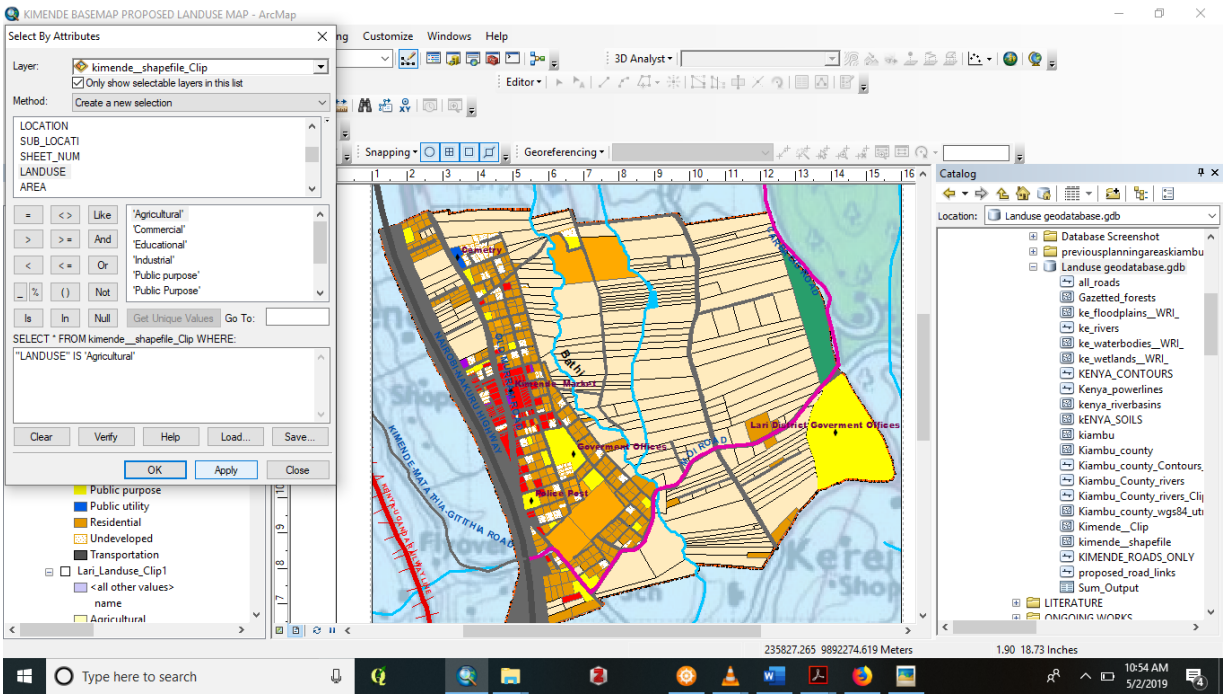

Figure 15: Running a query in the geodatabase.

The results produced by the query

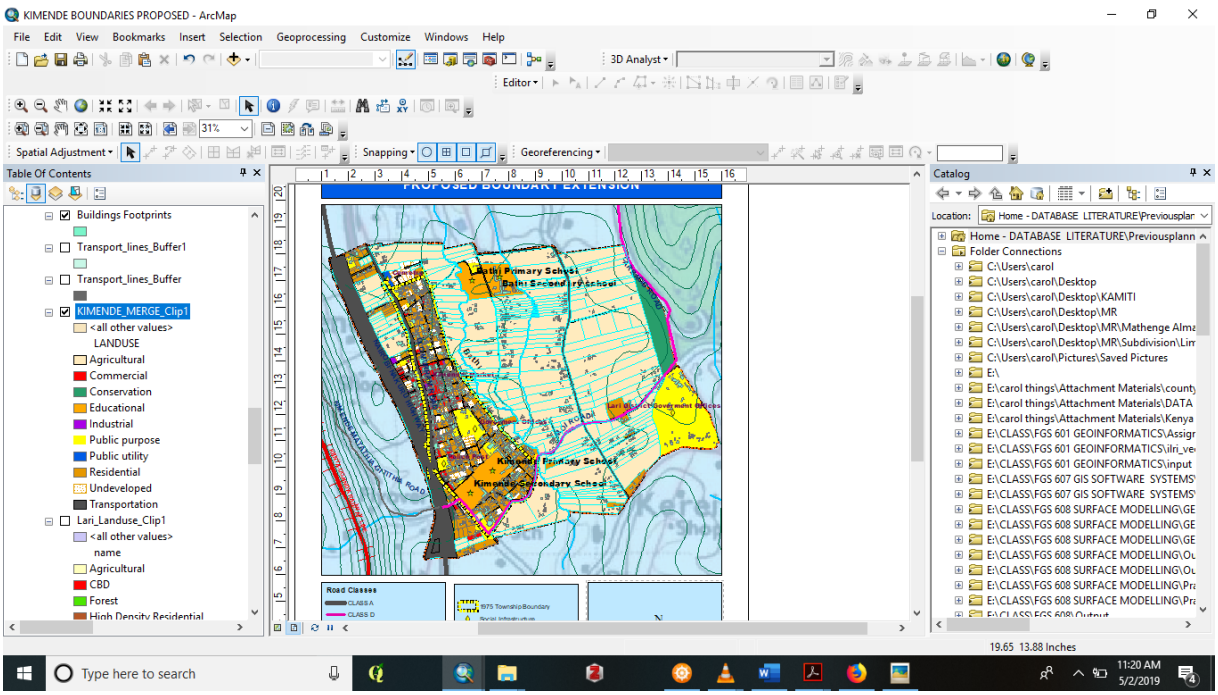

Figure 16: Showing query results

4.2 GIS for creation of a base map

The created database was used to create the 1975 Township Map. This was achieved through scanning of the existing hard copy map, adding it into a GIS environment that is ARCGIS, georeferencing to give it an accurate spatial placement on earth surface and finally digitizing it so as to convert it into a digital format. This was followed by Creation of an attribute table so as to hold the various characteristics of this map. Lastly a map was designed to aid visualization of this specific map in digital format.

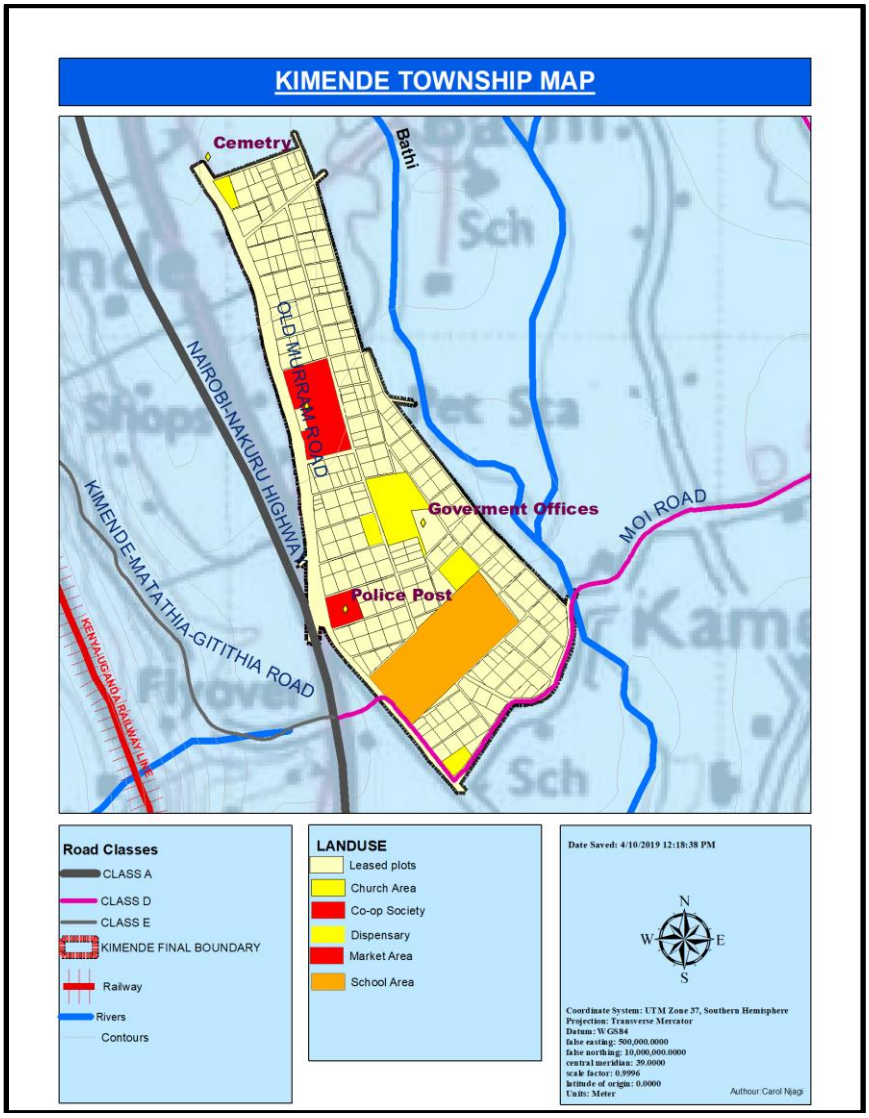

Figure 17:1975 Township map

4.2.1 Justification of the proposed Boundary.

Kimende has tremendously grown over time with its growth going beyond the 1975 township boundary. This was evidenced by the fact that majority of the most crucial facilities and developments paramount to the residents of Kimende were located outside the township boundary. That therefore formed the basis for boundary extension to accommodate all those changes not only for the current demand but also for sustainability of the future generation. This boundary extension was guided by various structuring elements as discussed below.

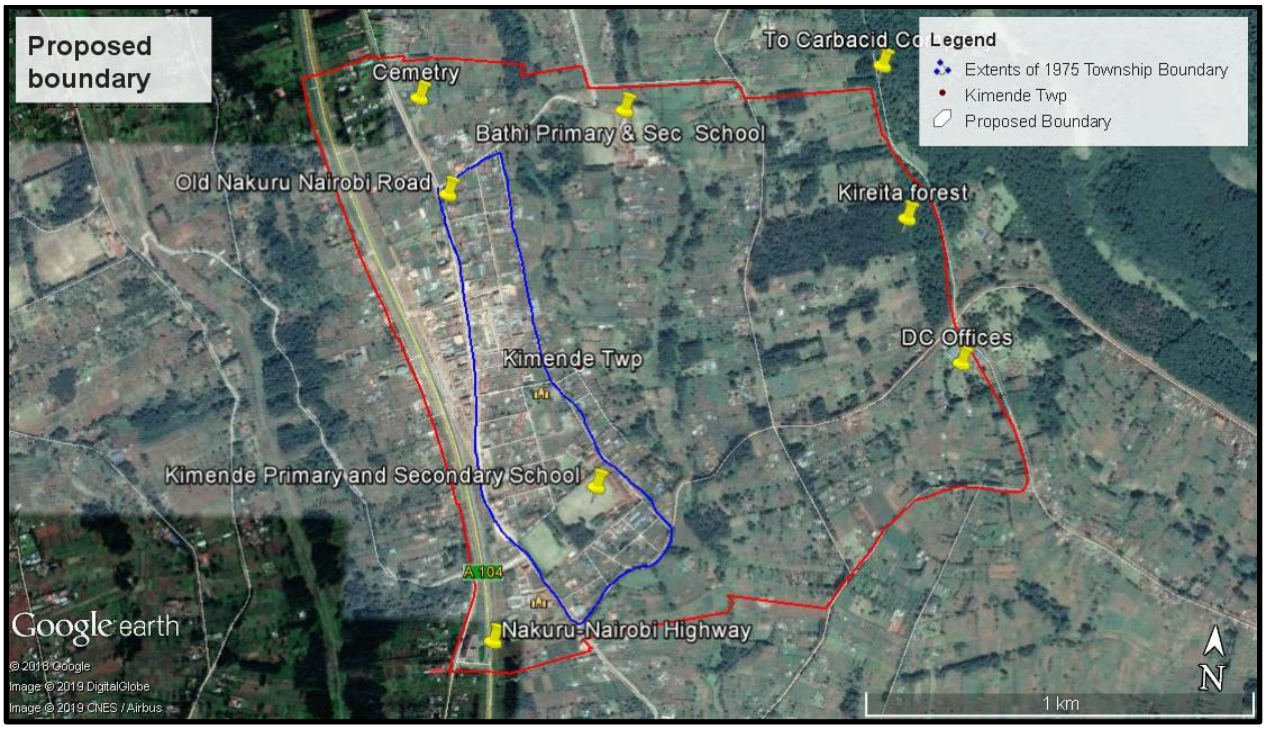

Figure 18: Google earth map indicating major land uses that informed boundary extension.

To the North there is a public cemetery meant to serve Kimende town and its environs residents. Such a facility is indispensable to any township as the dead have to be buried regardless whether they own or don't own a parcel of land. Bathi primary and secondary schools are a crucial educational facility serving the populace of Kimende town and its neighbors. Hence it was important having it incorporated in the township boundary.

To the north east exist a road headed to Carbacid Company defines the edge of the township boundary, as it falls along the boundary of the existing Kireita forest.to the extreme east there exists Kireita forest an important natural resource to Kimende. Part of it was captured in the township boundary because the residents derive direct benefits from such as firewood, timber and its products. It also serves as great tourist attraction due to its endowment with wildlife, various hiking trails and caves. All this if well exploited can spur a lot of positive growth. To the south east, there exist several Government offices such as deputy county commissioner offices, DC's. Educational offices, agricultural offices, water offices, Do' s offices, etc. All these provide administrative services to the people of Kimende.

Lastly to the south west we got the busy A104 Nakuru-Nairobi Highway which technically forms the end of the town. Terrain beyond this point limits meaningful growth of the town due to presence of the steep escarpments.

Considering all the above and many more developments the study saw the importance of expanding the 1975 township boundary to the proposed boundary so as to contain all the 9 land uses as well as absent land uses that are vital to Kimende.

4.2.2 Base map of Kimende Township

Secondly a base map which was very necessary for any planning assignment was created. This was achieved through adding the new proposed boundary shapefile into the ARCGIS environment. Various datasets that were obtained and stored in the geodatabase were added and overlaid for instance building footprints was overlaid onto the existing parcel information. Clipping of information that was going beyond the proposed boundary was done as well.

Lastly visualization of all the spatial elements was done guided by cartographic standards in order to produce this Base map. This map is dynamic since as it can be produced according to the user's

preference and any changes in them can be made fast without any cost implication as data is available.

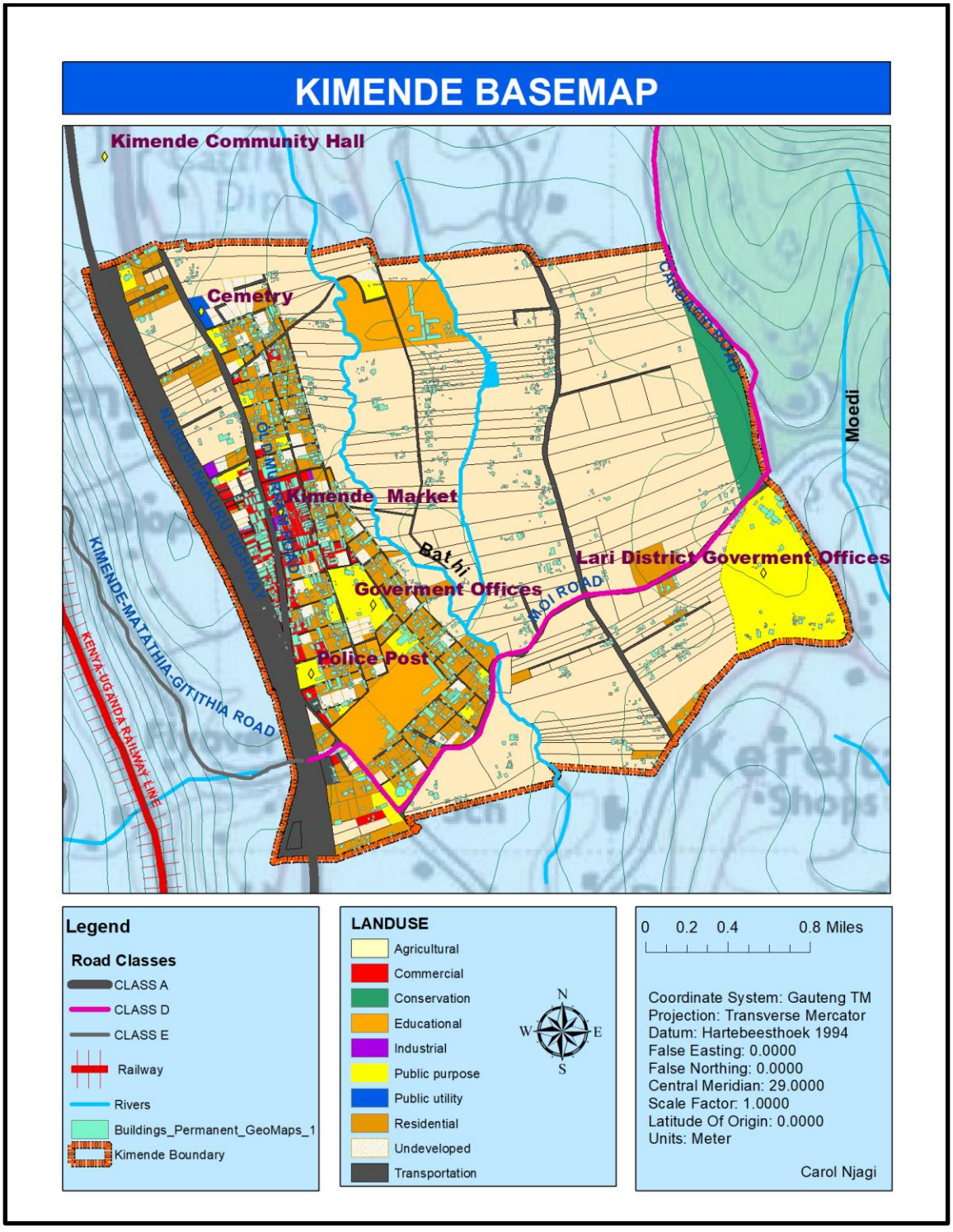

Figure 19: Kimende Town Base map.

4.3 A proposed land use map

The calculated land requirement showed below formed the basis of our proposal land use map. It is calculated from what exists and comparing it against the planning standards to obtain either a deficit or a surplus for each land use.

CODE	LANDUSE	AREA (Ha) Existing	PERCENTAGE (%)	Land use Requirements	Deficit (-) Surplus (+)	Acreage needed (Ha) Proposed
	Agricultural	127.41	65.26%	-		
	Commercial	5.06	2.59%	6.8%	-4.21	8.2
	Educational	9.17	4.69%	9.4%	-4.71	9.2
	Industrial	0.22	0.112%	8.7%	-8.588	16.77
	Public Purpose	13.74	7.038%	12.2%	-5.162	10.07
	Public utility	0.27	0.138%	3.8%	-3.662	7.15
	Residential	21.37	10.95%	57.64%	-46.69	91.15
	Transport	43.43	22.25%	-	-	
	Undeveloped	4.96	2.54%	-	-	
	Conservation/ Recreational	3.73	1.91%	5.1%	-3.19	6.22
	Total				73.02	148.76

Table 10: Analysis of the distribution of existing land uses and their respective land requirements

A tabular analysis of the distribution of existing land uses and their respective land requirements the

above analysis was made possible by various mathematical operation offered by ARCHGIS calculations such as calculate geometry to obtain the total areas, field calculator and summarize to get summary of various statistics as indicated above.

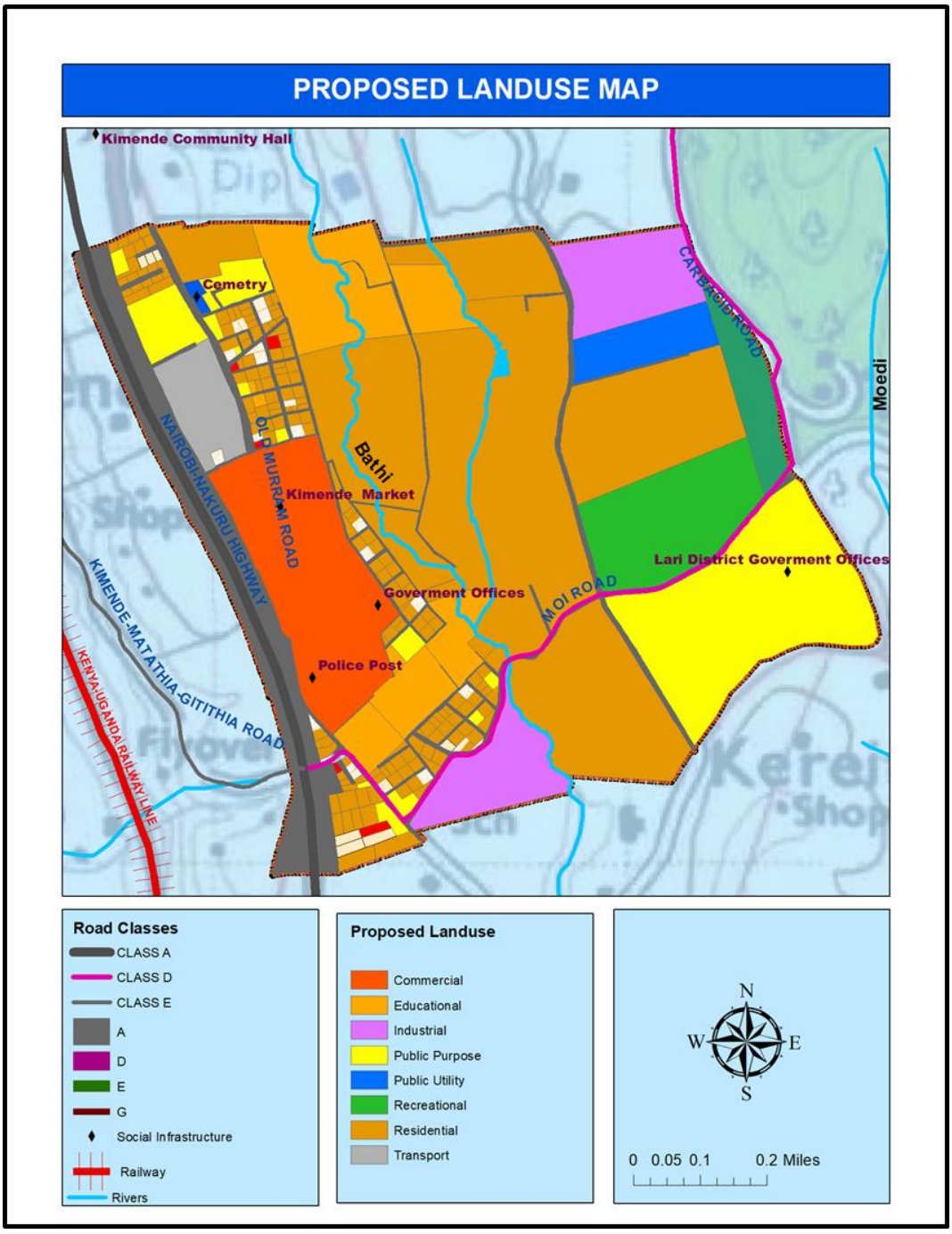

Figure 20: Kimende Town proposed land use map.

4.4 Comparison of the current/existing land use of Kimende town alongside the planning standards.

4.4.1 Extension of the 1975 Township boundary map.

One of the evident things that arose from this study was that, due to factors such as population growth, strategic location of the town, new upcoming needs of the residents of Kimende town it goes without saying that an additional area to adequately cater for all the land uses was a key necessity. That's why one of the proposals was extension of the township boundary from 35.88Ha to 195.23 Ha. This was also to allow for sustainable planning not only for the current population but also for the future generation.

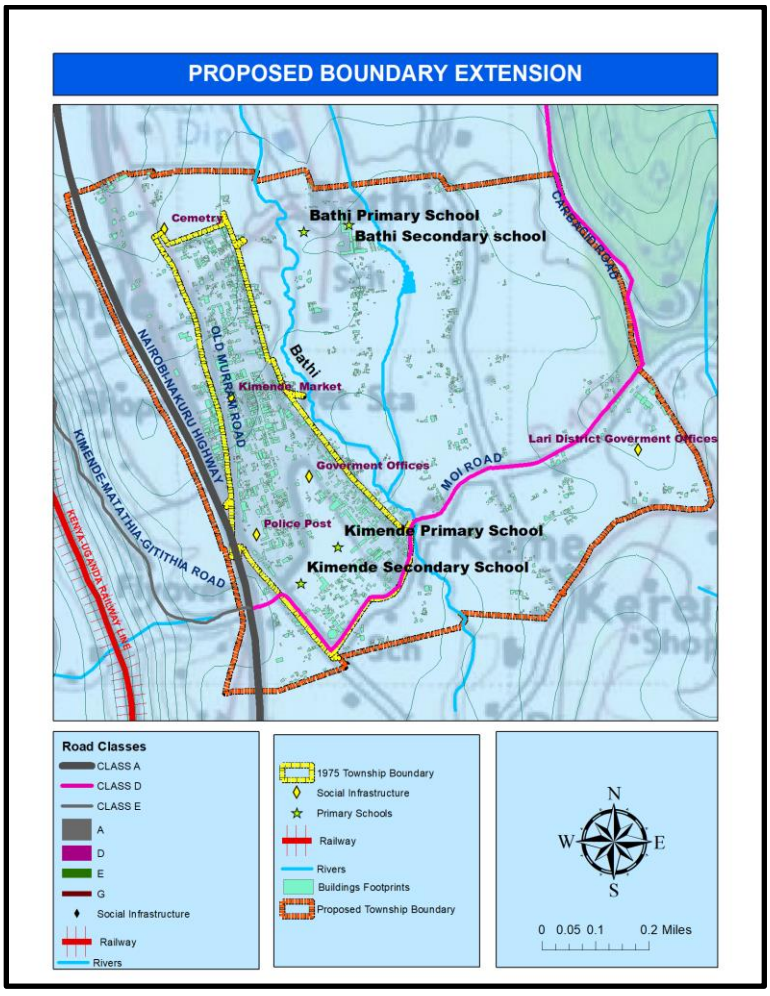

Figure 21:First boundary proposal

4.4.2 Commercial land use

A town center offers commercial and other related services used by the town's population including the inhabitants of its hinterland Rural area. The most important requirements for a town center are geographic centrality, accessibility to vehicles and pedestrians, ample space for parking and having four different degree of completeness in separating pedestrians from vehicles in town center, these are:

a) Constructing a bypass or relief road.
b) Interrupting continuity of streets within the center by bollards or other means.
c) Removing vehicles from streets and provide vehicular access and parking at the rear of buildings
d) Providing vertical separation of vehicles and pedestrians by constructing roads and pedestrians' ways at different levels.

In Kimende the A104 road Nakuru Nairobi highway serves as a bypass for Kimende where if one has no business to transact in the town just passes without making as stop.

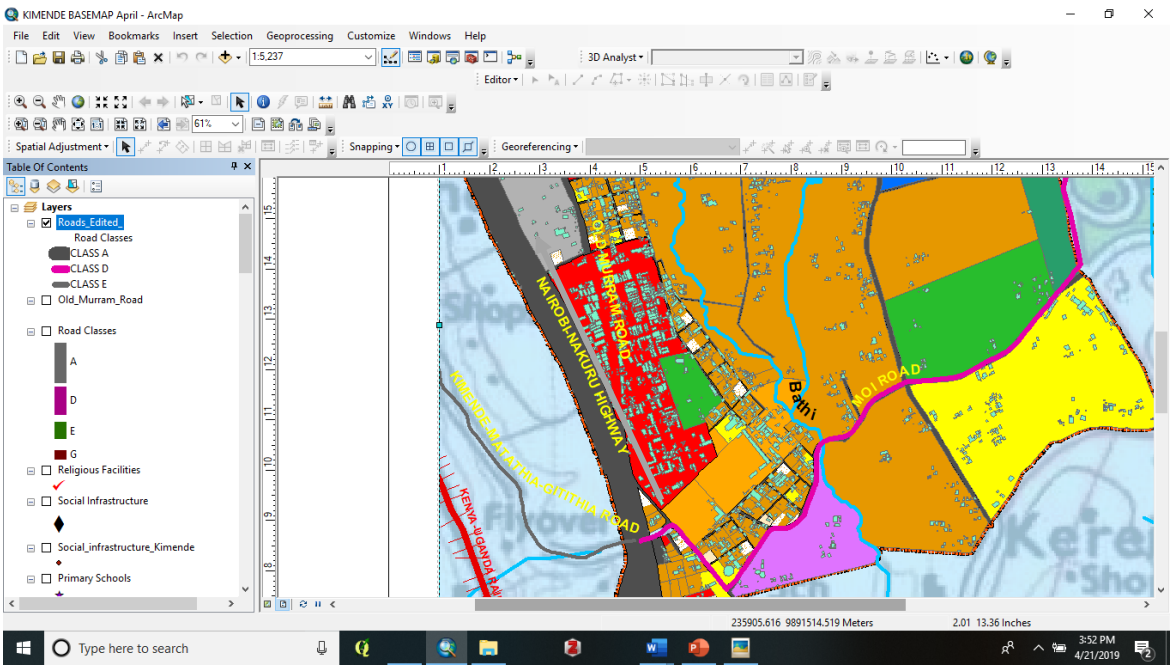

Figure 22: Showing Kimende A104 Nakuru-Nairobi Highway.

The other 3 degrees are some of the existing challenges that have to be addressed so as to make

Kimende an ideal commercial center.

The existing area under commercial activity stood at 5.06 Ha which represented 2.59%of the proposed township area whereas the planning standards allowed for a minimum coverage of 6.8% of the township area to be under commercial activity. This has therefore created a deficit of 4.21%. In order to meet this gap an additional 8.2 Ha and above has to allocated to this land use as indicated in the proposed land use zone map.

4.4.3 Educational land use

The provision of learning facilities and their land allocation depend on the age of the pupils/students and the size/number of the pupils/students. Kimende township had 4 public institutions which serve the population of not only the town(urban)population but also the area outside the proposed boundary. These schools were Bathi primary and Bathi secondary school, Kimende primary and Kimende secondary school.

For instance, going by the current enrolment of primary school going children of 6-13 years, Kimende primary had a population of 771 pupils. It was a two streamed school sitting on a piece of land measuring 2.43 Ha.

According to the planning standards a primary school on establishment as a single stream should have a minimum of 3.9 Ha. Each class from classes 1-8 should have a maximum of 40 pupils all of which should be residing within a walking distance of 500M-2KM.

This therefore means, Kimende primary school had not met the minimum planning standards on education since it was already sitting on a 2.43Ha of land yet it's a 2 streamed school. Hence additional land needs to be set aside for its expansion. This also applied to Kimende secondary school which sat on 1.58m yet the minimum land requirement for a single stream secondary school serving a catchment population of 25000 should be 3.4 Ha. It should as well be within a minimum

walking distance of 500m to 3KM.

In the proposed land use education had a deficit of land and required an additional 9.2 Ha so as to meet the minimum planning standard as stated above. That land is to be distributed to the 4 public schools going by the deficit each school exhibited.

4.4.4 Industrial land use

These areas provide suitable accommodation for the following types of industry; heavy and manufacturing, and noxious industries with large waste; large scale and users industrial plants; industries requiring excellent national/ international communication network; and industries requiring close links with other firms e.g. those firms which produce component parts for the same product or those involved in separate stages of the same industrial process. Accessibility to labour, communication routes, and ample supplies of power and water and sewage disposal facilities are of prime importance. Separation from residential areas through buffer zones is essential.

In Kimende the space under industry within the township is only 0.22Ha was quite low as it represented only 0.11% of the total proposed township. It fell way below the planning guidelines that requires 8.7 % of total area of a township to be set aside for industrial land use. In the current proposal 16.77Ha was set aside to adequately accommodate industrial activities which play a very crucial role to Kimende. These industries could include but not limited to juakali sector shed, sawmilling due to the presence of a forest, milk processing since the area is a highland area dominated by dairy Farming. Lastly, a leather tanning industry for the hides and skin obtained from the sheep and cattle which is highly dominant in the area.

4.4.5 Public purpose

This land meant for activities such as and not limited to health facilities, administrative areas (Dc's, chiefs offices, town and county halls, police stations, law courts, prisons/remand homes),

community centers, religious institutions, fire stations, libraries and post offices. Initially the township plan of 1975 allocated only 3.588 Ha representing 10% of land under public use which was slightly below the standard by 2.2% as minimum requirement should be 12.2 %.

Due to the immense population growth that had taken place within the proposed township boundary the total land under this use is 13.74 Ha representing 7.0345%. This fell short of the 12.2% requirement hence an additional 10.07 Ha representing 5.16% deficit was needed to bridge this gap.

In making the proposal several things had been considered. Since there were two government offices located separately namely (subcounty offices and the district offices) they were combined into one so as enhance service delivery. The public land under the subcounty office in town was proposed that it could be utilized for recreational purposes such a playing field or a park since Kimende had none at the time. The youths relied on the playground belonging to Kimende primary school.

4.4.6 Public utility

This includes services such as water, sewerage, garbage collection, telephone, cattle dips, tree nurseries, agricultural produce collection Centre such as Tea and Milk. From the information provided by Limuru water and Sewerage Company, there was no sewerage connection in Kimende. Similarly, piped water connection had not covered the town sufficiently as indicated by the same service provider which was mandated to service the area. The biggest challenge to this being old water pipes laid down in 1992 were worn out and small in size hence needed immediate replacement so as to meet the current water demand. The only public utility visible in Kimende was the garbage collection points near the market area and the unused cattle dip located next to Bathi primary school entrance. They cumulatively added up to 0.138% of the proposed township

area which fell short of 3.8% minimum requirement creating a 3.662% deficit. Hence at least 7.15 Ha had been set aside for this use in the proposal.

4.4.7 Transport land use

Urban road reserves require more generous space provision because of additional street furniture and infrastructural facilities that have to be provided. In most instances, the road has to accommodate multiple functions that have to be independently provided in design. Way-leaves for trunk services such as water and sewerage, underground telephone cables and high voltage power lines, when provided along road reserves require additional provision.

Further, the role of the informal sector in job creation in urban areas has now been recognized. Most of the informal activities are footloose and heavily dependent on passing trade. They therefore require specific provision when located within road reserves.

Because of the above reasons, the following urban road reserve widths were recommended:

Primary Distributors	Major communication routes	**60m.**
	Important through – routes	**30-36m**
District Distributors	Spine roads and roads in commercial or industrial area	**25m**
	Bus routes	25M
Local distributor roads	With no direct vehicular access to Individual plots	18M

Local Distributors	Major access road exceeding 150m in length	**15m.**
	Access road not exceeding 150m in length (normal Residential Street)	**15m.**
	Access road not exceeding 150m in length (normal Residential Street)	**12M**
Access Roads	Cul-de-sacs or short connecting road not exceeding	60m **6m- 9m**
	Service lanes Cyclist lanes Footpaths	**6m** **3m** **2m**

Table 11:Urban Road Reserve Widths.

In Kimende town, one of the biggest challenges that came out strongly was the issue of road encroachment which had reduced short connecting Roads expected to be of 6-9 m to 3 meters. (Refer to the figure below.) This highly inhibits efficient circulation of people in the township.

In town particularly, there were informal trading activities which occupied roads as proper road reserves had not been laid out that allowed for hawkers to operate. In the proposed land use plan roads have been expanded to be at least 6m and above and appropriate road reserves left out to

cater for hawkers.

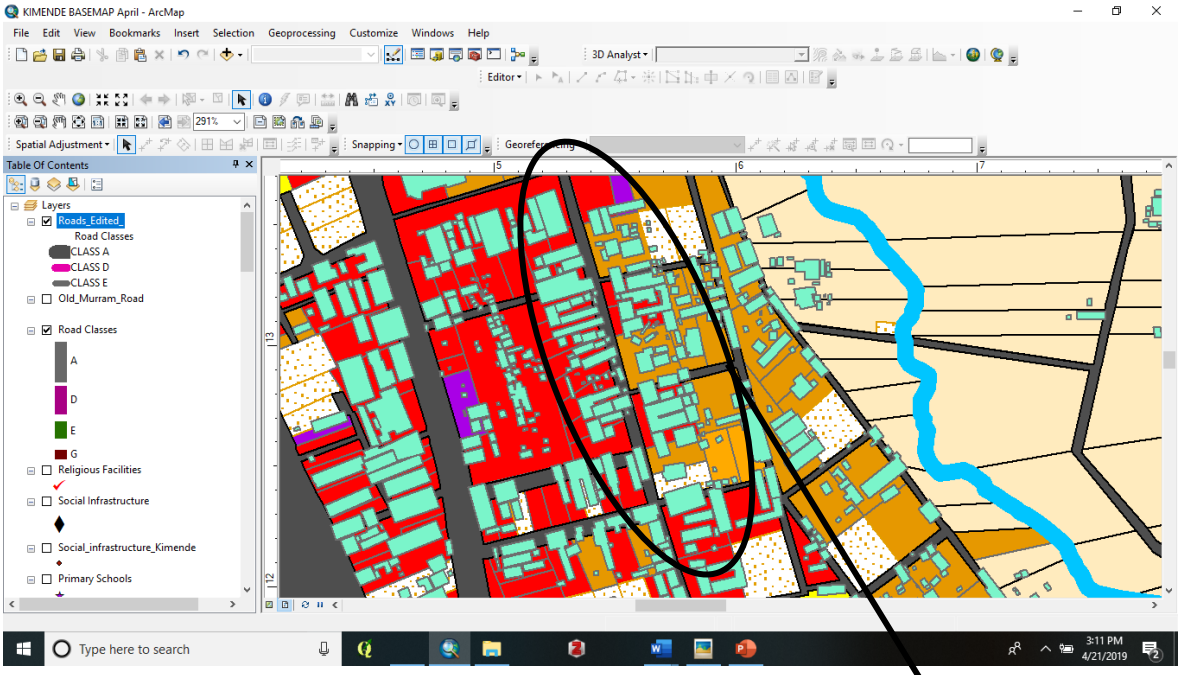

Figure 23: Illustration of encroachment of buildings into roads.

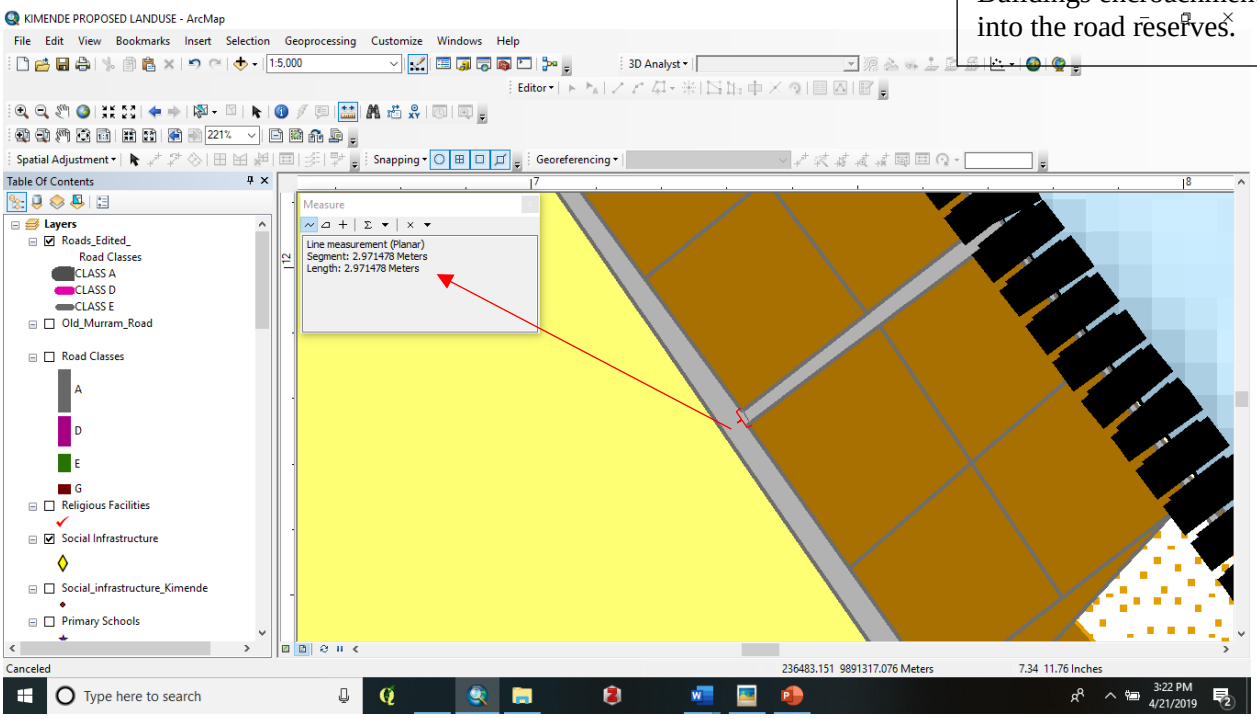

Figure 24: Illustration of extremely narrow road of 2.97

An access road of 62 meters in length measuring 2.97meters instead of the required minimum of

6-9metres.

4.4.6 Residential land use

This is the land use that occupies the biggest percentage in any urban area with the standard minimum of 57.64%. The land under this land use in Kimende stood at 10.95% which creates a deficit of 46.69%. This therefore meant that to be in a position to meet the residential needs of various categories which are low density, medium density and High density an additional 91.15Ha was to be set aside. The proposed land use map has catered for that as well.

Chapter 5: Conclusions and Recommendations.

Conclusions

Cities are systems of tremendous, ever-evolving complexity. Responsibly guiding an area's development requires spatial information that's robust, nuanced and constantly updated, as well as the problem-solving skills to apply that information. This challenge has made geographic information science and technology (GIST) invaluable to urban planners.

From the study, the three study objectives were all achieved through the help of GIS. A base map of the study area was created using the various techniques GIS offers. Secondly a proposed land use map was made after identification of lands use deficits taking into cognizance the existing developments. A comparison of the glaring shortcomings brought about by the 1975 township plan vis a vis the planning standards was done.

In this project, GIS brought out several advantages that encourage its use in land use mapping

First and foremost, the geo database created stored all spatial and non-spatial data obtained that was necessary for the production of a development plan. Secondly, the same data was updated and can be updated with ease at any time hence prompting production of up to date thematic maps for use in daily planning assignments. Additionally, visualization and modeling of various scenarios was possible since GIS had the capabilities However, the deficits identified indicate glaring opportunities which counties can explore by ensuring their townships are well planned as planning is key and indispensable for any town or counties development.

Recommendations

In order to attain maximum benefits of GIS in urban land use planning the following steps should be undertaken in Kenya.

First, unplanned towns are a general issue across the country hence counties should prioritize plan

preparation to salvage uncoordinated growth of urban centers. Secondly, all Counties should adhere to section 110 of the constitution through enforcement to ensure preparation of GIS based development plans within the first two years of any county government being in office. To achieve this, GIS should be inculcated practically instead of the theoretical approach in urban and regional planning educational curriculum. Moreover, It is very important to fast track digitization of the existing maps and development plans so as to promote tapping of GIS capabilities in planning of these areas during planning and re-planning of all the towns in Kenya. Finally, there is need to add value to the planning process by hosting digital development plans online and make them accessible to the public more easily and also be able to include public participation in that forum. Future research can look into ways of preparing plans digitally, through involvement of all key stakeholders regardless of their physical location.

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