Development of a Digital Cadastral Database to Analyse Road Encroachments in Buruburu Estate, Nairobi

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Abstract

Today, technological advancement is the major driving force in changing the face of the spatial information around the world. The high spatial resolution satellite imagery tends to revolutionize the Mapping discipline. The GIS database technology for storage of large datasets, data management, analysis and update facilities has had the greatest impact on the spatial information environment. The study was aimed at development of a digital cadastral database for detection and analysis of road encroachment. The study covered phases III, IV and V of Nairobi's Buruburu estate. The methodology employed in the study involved use of GIS software to develop a cadastral database which contains both spatial and non-spatial data. Three Registry Index Maps (RIMs) were scanned, georeferenced, cropped and mosaicked. Vectorization was done resulting into the creation a cadastral database with information on area of parcel, parcel number and parcel owner. Overlay with high resolution satellite imagery was done to establish whether there were buildings constructed on the road reserves.

Using a Structured Query Language (SQL), the database was queried to obtain information on the parcel owners whose buildings encroaches the road reserves. Statistical analysis using tables, graphs and charts was done to evaluate the total area encroached by the buildings. Encroachment maps were then developed. The Digital Cadastral Database prepared clearly presents a much better medium for land information management for the urban road reserves compared to the current method which depends on hard copy maps. The project shows the benefits of integrating Remote Sensing, cadastral survey and Geographic Information Systems approach in land management. As a result, it is concluded that Geospatial databases form the basis for this new technology as it provides information linked to the current condition on the ground and therefore provides a framework upon which developments on land can be monitored. Adoption of digital cadastral databases in management of land resources is imperative.

Key Words: Encroachment; GIS; Buruburu; Surveying; Cadastral Database.

Introduction

The existing cadastral system in Kenya has served the country well for the last 100 years. However, due to rapid technological and technical changes, it is evident that the system can no longer effectively cope with the demands of a modern economy. If the country has to attain its vision of industrialization by the year 2030, there will be a need to modernize the current cadastral system in order to provide a rigid framework upon which the industrialization concept can be anchored. Before embarking on the modernization strategy, there is a need to assess its strengths and weaknesses with a view to carrying out the necessary reforms. In any jurisdiction, cadastral system consists of five components or pillars: land survey, land registration, land valuation, land control and regulation and land information management (Mulaku, 2009). Land information management, in which Cadastral database is a component, collects, manages data then generates and disseminates all land information for the optimal use and conservation of the land resource (Fig. 1). Kenya has a comprehensive multi-modal infrastructure system of roads, railways, maritime transport, pipeline transport and air transport networks. As well, it has comprehensive land registration system that has been in operation for over a century. However, within the past period the transport system has suffered from under-investment, inadequate maintenance and inappropriate policy environment to the point that it now poses a serious impediment to the country's economic growth. Despite the fact that cadastral system in Kenya has been in operation for over a century and more than four million land parcels have been surveyed, the land records are still kept in a manual format. This system is not only inefficient in land data management but is also beset with inadequate storage space, which hampers quick cross-referencing of records and constrains the orderly and timely updates of databases in use. In this state, data and information are not easily accessible and as a consequence, important developments on land like construction of roads and buildings can be made on unreliable information. Before buildings are constructed, development plans have to be authenticated and approved by Physical Planning Department according to building codes and regulations. The buildings have to be constructed within the parcel to occupy a certain percentage of the total area of the parcel. Maintenance of road reserves is imperative since most of underground utilities like sewer lines, power and telephone cables are normally laid along these reserves. Buruburu is a residential estate. Here, buildings have been constructed beyond the legal boundaries of the parcels. Assessing from the QuickBird image, it is clear that there are those buildings constructed along road reserves while others encroach into the adjoining parcels. Since in most cases fixed boundaries are not indicated by physical features or marks such as beacons on the ground just like in the case of general boundaries, people often tend to construct building extensions on road reserves. This is due to the fact that they lack clear knowledge on boundary position of their parcels and adjoining roads. Poor survey will also lead to encroachment if the horizontal controls are not well established.

Nairobi is the Capital City of the Republic of Kenya. It is the largest administrative, commercial, and industrial centre in the country. The city has experienced a rapid population growth due to rural-urban migration in search for employment and better living conditions. As a result of this increase, the scarcity of land for residence has grown altogether with rapid and excessive rise in the value of the available land. The use of unapproved development plans, long procedures taken to approve development plans, ignorance of the people regarding the information about width of road reserves, poor governance, and bureaucracies have all led to construction of buildings within road reserves. This is a major problem in efforts to expand the road network so as to reduce the traffic volumes because those people who have constructed buildings on road reserves have to be displaced if such an expansion has to be undertaken. Unavailability of a well monitored and frequently updated LIS that has maps and the status of the land designated for these road reserves has led to encroachment. Road encroachments vary in intensity from parcel to parcel. The study therefore sought to come up with a cadastral database which shows a direct linkage of spatial data (RIMs) and non-spatial data like parcel number, area of the parcel, parcel owner and date of registration of parcels. As well, the status of the parcels was evaluated by spatial analysis through overlay operations with high resolution satellite image to establish whether there is road encroachment on each parcel adjacent to the road.

The main objective of the project is to develop a digital cadastral database through application of GIS which will be used to analyse road encroachment in Buruburu Estate. The specific objectives are: (i) To develop a digital cadastral database representing land information for the area of study using Geographical Information System (GIS). (ii) To map encroachment along the roads in Buruburu estate by integrating Remote Sensing using high resolution satellite imagery and GIS. (iii) To create encroachment maps showing the land parcels with buildings that have been constructed illegally on the road reserves. (iv) To perform spatial and statistical analysis of the results obtained.

The study covered part of Buruburu estate to evaluate those buildings that have been constructed illegally on road reserves. This project was set to show the advantages of digitizing the land records to form a cadastral database since it will be easy to perform analysis on the basis of how the resources are managed. In this case, the resource is land, which happens to be the most sensitive resource to all groups of people, literate or illiterate, poor or rich, men or women according to Wates (2000). The project sought to integrate data on road reserve (the way buildings have been constructed) and boundary data of land parcels together with their attributes such as area of parcels, parcel numbers and parcel owners. The map which shows parcels with encroachments was developed using ArcGIS 9.2 software. The research therefore was limited to phases III, IV and V in regard to structures or parts of buildings that encroach into the road reserve. The three phases were chosen because the data was readily available.

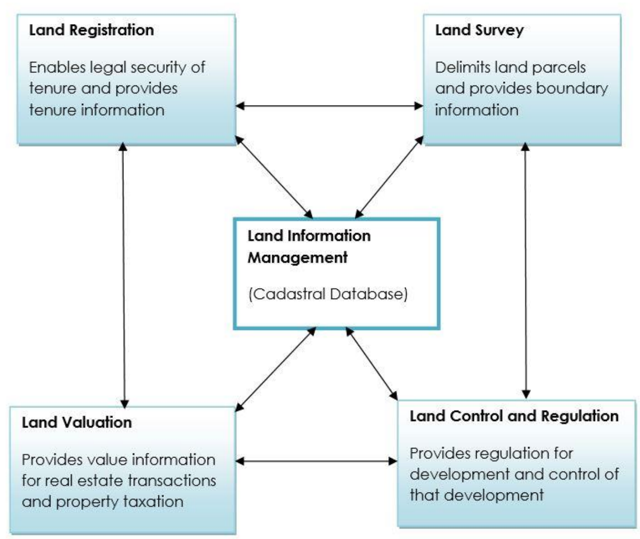

Fig. 1: Components of a cadastral system (Mulaku, 2009)

There are many challenges facing the current cadastral system in Kenya which are either technical, technological, or administrative in nature. They include:

- Existence of Multiple Reference Systems;
- Manual/analogue cadastral records;
- Existence different or multiple land registers
- Multiple Land Registration Systems/acts.

Encroachment is defined as unlawful entering (gradually and without permission) upon the land, property, other possessions, or the rights of another. Some of the causes of road encroachment include: (i) Pressure on existing limited land resource makes people create extensions on road reserves. (ii) The use of unapproved development plans (PDP) during construction of buildings. (iii) Lack of clear information by parcel owners on the legal boundaries of parcels and road reserves. (iv) Bureaucratic governance and lack of transparency in management government resources especially land resource.

Study Area

The study was conducted in Phases IV, V and part of Phase III because some Registry Index Maps were missing in Survey records office. The study area lies within Northings 9858734 m to 9858231 m and Eastings 264234 m to 263876 m (UTM projection). The three phases cover an approximate area of 559000 M^2 which is equivalent to 55.9 hectares.

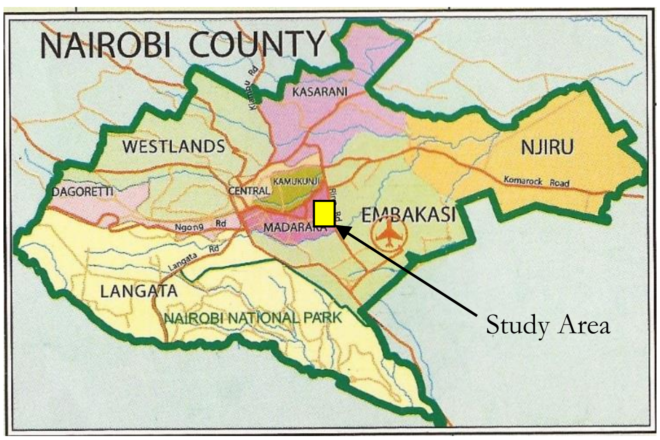

Fig. 2: Location of the study area

Data Requirements

Table 1: Project Data

Data	Source	Projection
Registry Index Maps (RIMs)	Survey of Kenya (SoK)	Cassini Projection
QuickBird Satellite Image	DRSRS	UTM/Arc1960
Data on Road Reserve Widths	KRB	UTM/Arc1960
Excel Data on Land Owners	KNBS	N/A

Fig. 3: QuickBird satellite image covering study area

Cadastral Database Design

The process began from data collection, database design, overlay operations in ArcGIS environment and finally mapping and analysing the road encroachment. The process of developing a database or indeed any information system is essentially a process of model building (Kang-Tsung, 2008). There are basically four steps of developing a cadastral database.

- External modelling
- Conceptual modelling
- Logical modelling
- Physical modelling

External Modelling is the initial stage in database design and it involves assessment of user needs. It is the determination of a finite set of potential users of a database, their information needs and hence the data that is required to satisfy those needs. *Conceptual Modelling* is the synthesis of all external modelling in an entity relation diagram (E-R) showing all the entities involved, their attributes and relationships. The process of developing a conceptual model focuses on the question of "what" the system will do, termed as system analysis. *Logical Modelling* is the mapping of a conceptual model into a logical model when using Database Management System or setting up table schemas using Relational Database Management System. The process of developing a logical model focuses on questions of "how" the system will implement the conceptual model, termed system design. *Physical Modelling* involves defining where the data physically resides, how data is processed and the access protocols. It is largely done by the DBMS and depends on both hardware and software. In this research, ArcGIS database model with SQL capabilities was employed as discussed in subsequent sections.

Methodology

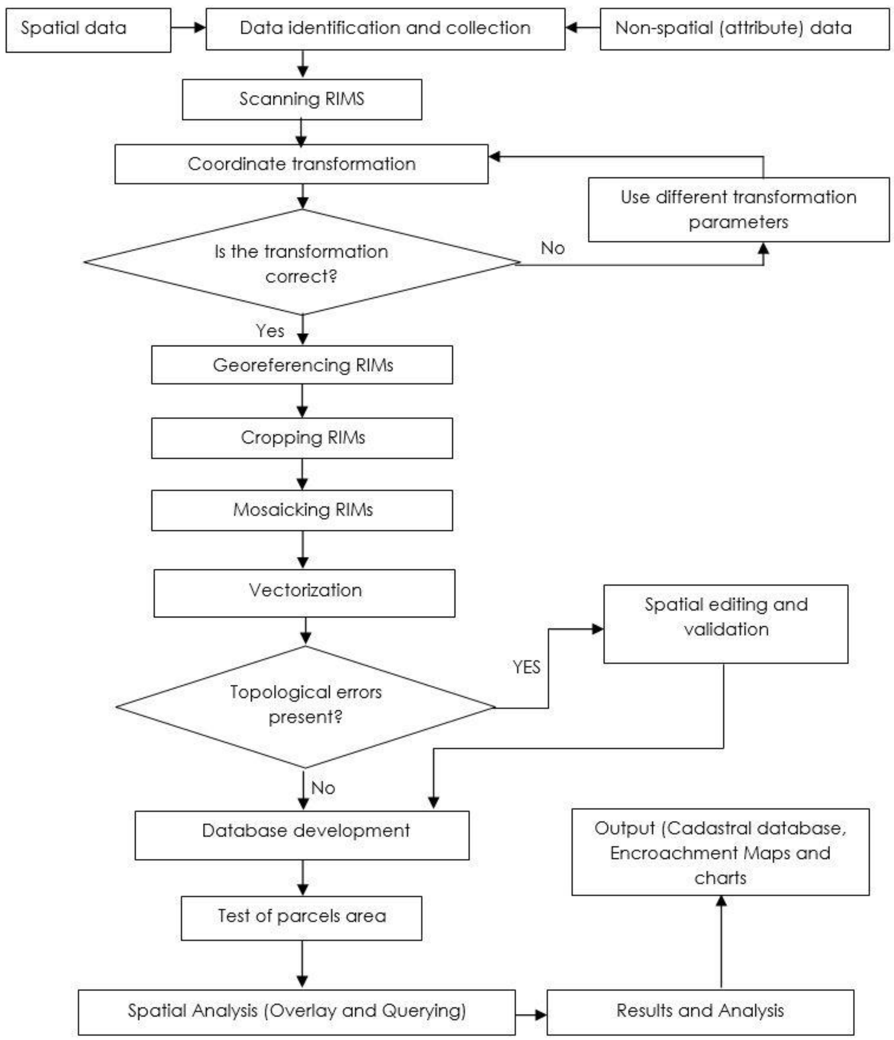

Fig. 4: Methodological Workflow

Data Collection

The data collected was mainly secondary data. Since the project was aimed at analysing encroachments along road reserves in Buruburu estate, data on parcel boundaries was collected. Data on buildings was also obtained from the satellite image. From the users' requirements and in view of the general scope of the conceptual model, the following data was identified as being necessary.

i. Registry Index Maps (Scale 1:1000) – This is the spatial data and it contains the boundary information and the spatial location of land parcels. They also show parcel and block numbers.
ii. QuickBird Image (Spatial resolution 60 cm) – This spatial data gives information on the location and distribution of roads, buildings and other structures at different scales.
iii. List of parcel owners – The list indicates the name of parcel owners and their addresses. It gives attribute information of parcel owners.

The main sources of this data were the Survey of Kenya (SoK), Kenya National Bureau of Statistics (KNBS) and Department of Remote Sensing and Resource Surveys (DRSRS).

Scanning: Scanning of the RIMs was done at 300 dpi which was found optimal for the required resolution and the capability of the computer for handling the resulting data.

Before scanning, the RIMs were prepared to ensure the line widths are resolvable, line separation exceeds pixel sizes and unwanted data is opaque out. The maps were put on the scanner and then the specifications were set. This included scanning resolution and output file destination. Adobe Photoshop software was used to clean any dirt within the resulting raster images and to enhance the colour, contrast and brightness for easier interpretation of details in resulting image.

Georeferencing: This was done using Global Mapper software. Since the RIMs were in Cassini projection, coordinate transformation was done prior using the following 4-parameter transformation formula:

$$E_{UTM} = \lambda\cos\theta X_{CAS} + \lambda\sin\theta Y_{CAS} + T_X \qquad (1)$$

$$N_{UTM} = \lambda\cos\theta Y_{CAS} - \lambda\sin\theta X_{CAS} + T_Y \qquad (2)$$

Where, θ is the rotation angle, λ is the scale factor and T_X and T_Y are translation in X and Y axes respectively.

Taking $a = \lambda\cos\theta$=constant and $b = \lambda\sin\theta$=constant, then equations 1 and 2 above becomes;

$$E_{UTM} = aX_{CAS} + bY_{CAS} + T_X \qquad (3)$$

$$N_{UTM} = aY_{CAS} - bX_{CAS} + T_Y \qquad (4)$$

Where, **a** = 1.00037060000,
b = -0.0006888780,
$\mathbf{T_X}$ = 277446.05900
$\mathbf{T_Y}$ = 10000220.945

Equations 3 and 4 above were used to transform all Cassini coordinates into UTM coordinates using MATLAB program as shown in appendix A. The obtained coordinates in UTM projection system were then used to georeference the RIMs (Fig. 5). The reason why this was done was have a unified coordinate system for both the RIMs and the satellite image for efficient overlay operation s in ArcGIS environment.

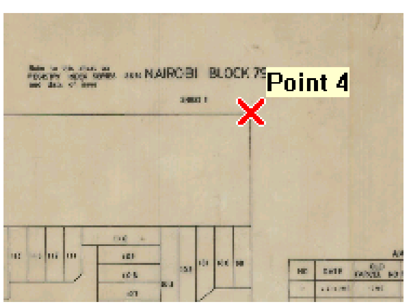

Fig. 5: Georeferencing RIMs using Global Mapper

Cropping RIMs: Cropping which is the process of cutting the unwanted parts of the map or image to reduce data volumes was done using Global Mapper software. Cropping was done along the grid margin since it would be easier to merge the resulting map with the adjoining maps. The digitizer tool was selected from the main menu which was used to crop the RIM. The option of cropping area feature and the output destination file of the cropped map were selected before the task was carried out.

Mosaicking RIMs: Before this task was carried out, it was ensured that the maps had been in the same projection. All input images must have the same number of layers. Global Mapper software was used to perform mosaicking task. A reference image was selected in the reference column of the cell array. This reference image acts as the baseline for contrast matching and determines the default output map projection, cell sizes and data type. A choice of the output file name, file destination and the matching method were all selected.

Digitizing/Vectorization: The georeferenced RIMs were vectorized through on screen digitizing using ArcGIS 9.2 software (Fig. 6). The vector data derived from the digitizing process was then stored for further analysis. Snapping tool was activated prior to digitizing so as to improve the way features meet and align at intersection points. Both general and interactive snapping were set during digitization. Snap tolerance was set to 2 metre. This way, for line themes, all line features coming together at an intersection will share the same endpoint and there will be neither overshoots nor undershoots. For polygon themes, there will be no gaps and overlap between adjacent polygon features. Since most parcels shared common boundaries, digitization was done once along these boundaries by using tracing tool to avoid the existence of gaps or overlaps. Digitizing outline width was set to be 0.5 m. On snapping dialog box, the boxes showing vertex, edge and end were all checked. This was done from layer to layer depending on the layer that was been worked on. The layers that were vectorized include: parcels, buildings, roads and railway line among others.

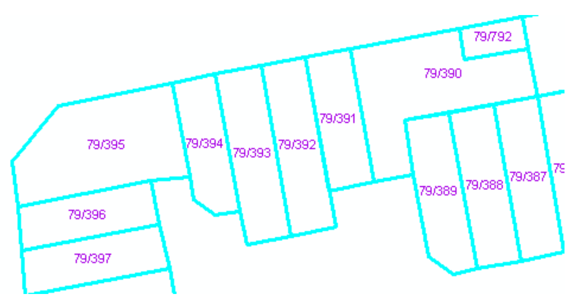

Fig. 6: Digitised land parcels

Attribute Data Capture: This is attribute data for the respective spatial data captured and includes areas in hectares, parcel numbers, parcel owners and identification whether there is encroachment on the parcel or it's pure abuttal. This data was entered carefully in the attribute tables of separate themes to ensure that accuracy, completeness and quality were maintained.

Data Editing and Validation

This refers to the process of detecting and correcting errors during spatial data capture. The aim of editing was to ensure the following was done: (i) All unclosed polygon features were closed. (ii) All required land parcels (polygons) were labelled. Labels were placed inside the polygons. (iii) All line features were connected to create topology (network connectivity). (iii) No overlaps or gaps between adjacent polygons.

Overlay Operations

Overlay involves merging or integrating of data from two or more data layers of same area to form new spatial data sets in the form of a new output data layer. Vector overlay relies on geometry and topology. All overlay methods are based on the Boolean connectors AND, OR, and XOR. An overlay operation employed in the study was Symmetrical Difference since it uses XOR connector. It preserves features that fall within the area extent that is common to only one of the input layers. It computes a geometric intersection of the input and update features. Features or portions of features in the input and update features which do not overlap will be written to the output feature class. Symmetrical Difference requires that both input layers be polygon layers as shown in Fig. 7.

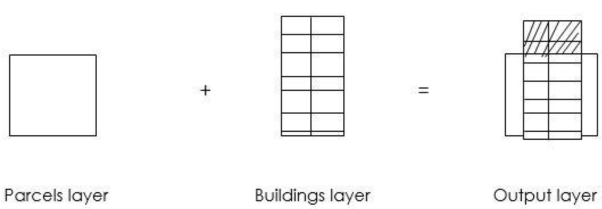

Fig. 7: Symmetrical Difference method of overlay

Digitized parcels layer was overlaid on buildings layer and the features of interest were those buildings that are constructed beyond the legal parcel boundaries (illegal building extensions). These buildings were then digitized in different output layer of encroachments. Feature layers that were overlaid had been spatially registered and based on the same coordinate system (UTM plane coordinate system). The layers were also in the same zone (zone 37S) and same datum (Arc1960 for UTM) as shown in Fig. 8.

Fig. 8: Buildings and parcels overlay

After the overlay was done, those buildings that have been constructed beyond the legal parcel boundaries were digitized and stored in a different layer of encroachments. This was done for phases III, IV and V separately for easy interpretation and analysis of the results. The Fig. 9 shows an illustration on how this task was carried out. The blue colour indicates the road encroachments.

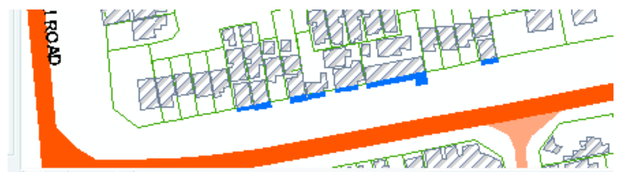

Fig. 9: Buildings with encroachments

Results and Analysis

The main objective of this project was to come up with a cadastral database for detection and analysis of road reserves. The cadastral database developed has the information of each parcel. The information includes parcel number, area of the parcel, parcel owner and the indication whether there is any encroachment on the parcel or it is pure abuttal. The Fig. 10 below shows a sample of the database developed using ArcGIS 9.2 software.

FID	Shape *	PARCEL_NO	PHASE	Owner
1	Polygon	79/698	5	FELIX ANGAINE
2	Polygon	79/699	5	LAWRENCE KIPROP
3	Polygon	79/700	5	DENNIS HADJI
4	Polygon	79/701	5	DENNIS KIPROTICH
5	Polygon	79/702	5	ADAN OLE SASINA
6	Polygon	79/696	5	CASPER BAYA
7	Polygon	79/703	5	PATRICK KULEI
8	Polygon	79/695	5	FRED MOMANYI
9	Polygon	79/694	5	FARIDA MOCHECHE

Fig. 10: Sample ArcGIS database

Analysing Road Encroachments

In the subsequent sections, road encroachments are discussed. The spatial location of the selected parcels with encroachment is shown in Fig. 11. The encroachments are shown in blue colour.

Fig. 11: Spatial location of parcels with encroachments

A total of 47 parcels out of 131 were selected. From the selected records, information such as parcel number, parcel area, phase number, parcel owner, parcel status and total area encroached was obtained. This information is crucial as it provides a framework upon which important decisions can be made. If for instance there is road expansion project to be carried out in the area, the parcel owners whose buildings are on the road reserves can be given a notice on the intended activity. This is possible if their contact addresses are shown in the cadastral database.

Table 2: Spatial results for phases III, IV and V

Phase	Number of Parcels	Area (M^2) Encroached	Peri. (M)	Building with Extensions
III	467	212	106	45
IV	612	324	238	67
V	596	159	112	19
Total	1675	696	457	131

Better decisions can be made when building layer data is combined with parcels layer data to map those parcels with encroachments. Using overlay analysis, it is possible to know the total number of houses with extensions on the road reserves. Overlay analysis which relies on both topology and geometry of datasets used, was possible since both buildings layer and parcels layer were in same projection. By using query operations, those parcels with buildings on road reserves can be queried as shown in the Fig. 11 above. The spatial measurements that were done include simple numerical values that describe aspects of geographic data. This consisted of measurement of simple properties of objects such as perimeter, area and direction. The use of tabular results for each road assists in evaluation and assessment of the magnitude of encroachments much easier than when analysis is done for the whole study area. More details are revealed when analysis is done for each road. The results shown in the Table 2 is used to generate the graphical results which give a better visual impression of the encroached area in the area of study.

The tabular results given above can be further analysed for better visualization using a graphical representation as shown in Fig. 12. From the graph, the magnitude of area encroached along each road can be visualized clearly.

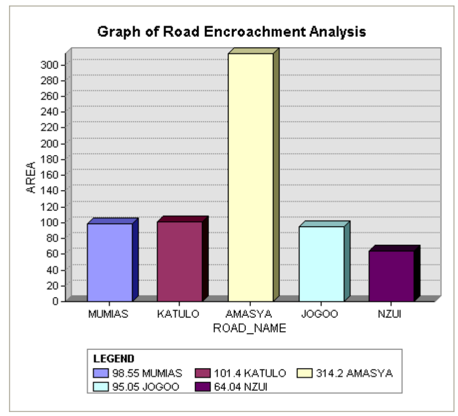

Fig. 12: A graph showing encroachments on road reserves

In order to facilitate the spatial visualization of the intensity of the encroachments, the maps that cover all these roads were created. The Fig. 12 above shows the road on which illegal building extensions have been constructed. From these results, it's therefore imperative for relevant authorities to know the parcels owners with these buildings so that they can compensate the owner of the land who in this case is the government. The names of parcel owners can be obtained from the database so created.

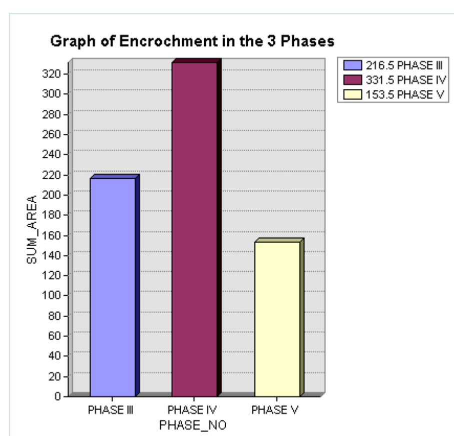

Fig. 13: Encroachment in phases III, IV and V

Fig. 13 shows sum area in square metres of land encroached per road in Buruburu. From the graph, it is evident that phase IV has the highest area encroached by illegal buildings. The information on the spatial distribution of the parcels in which the buildings are constructed is critical because it will assist relevant authorities like the City Council to know the names of those who own these parcels. A query is therefore performed on the database created so as to display names of parcel owners and the area that has been encroached as demonstrated earlier.

Table 3: Comparison of percentages of encroachments

PHASE	AREA (M^2)	PERCENTAGE
III	216.5	30.86
IV	331.5	47.26
V	153.5	21.88
TOTAL	701.5	100

The pie chart representation of encroachments gives a straight forward visual impression of the size of the encroachment in the three phases. From the chart in Fig. 14 below, it can be seen that phase IV has the highest encroached area in terms of percentage of total area encroached while phase V has the least.

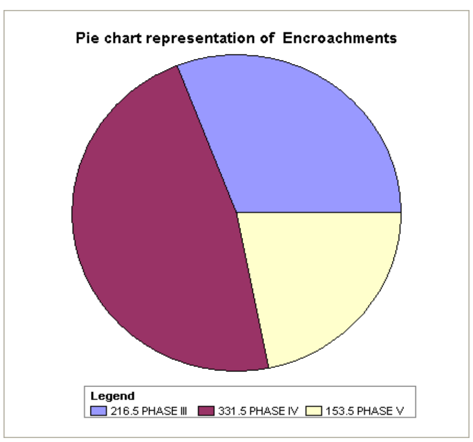

Fig. 14: A representation of total area encroached

Geo-tagging

This is the digital connection between the spatial data and a digital photograph or a picture. In this project, hyperlinking was applied in displaying the condition of the parcels and the buildings. A click on the feature would reveal the hyperlinked digital image together with the spatial location. This is a better inspection data than sketches. Fig. 15 shows a sample of the photographs of the houses along the road reserves. The buildings with extensions were identified on the image and their close range photographs were taken on the ground. The exercise was performed to verify the results obtained. The Fig. 15 below gives an illustration of hyperlinking.

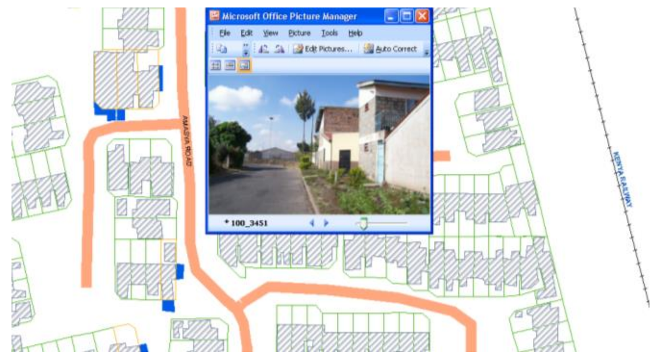

Fig. 15: Geo-tagging

Development of Encroachment Maps

One of the objectives of the project was to create encroachment maps for the three phases. The maps were developed as the final output of the project. The aim of developing these maps was to show the spatial location of those parcels with illegal extensions. Ideally, maps create good visualization than the database or tabular results since they show exact location of the buildings and parcels on the ground hence they enable easy assessment and analysis on the way physical developments have been done on land parcels. Features that were put in the maps include:

- Parcels
- Roads
- Encroachments
- Railway line

The encroachment maps created will be used to advise the policy makers on the appropriate action that need to be taken such as placing physical marks on the ground e.g. beacons to show the extent of the road reserves. Alternatively, there is a need for public sensitization exercise on the importance of the safeguarding the road reserves. The impacts of the road encroachments were discussed earlier in the introduction section but recommendations and conclusions will be handled in the closing chapter.

Fig. 16, 17 and 18 below shows the encroachment maps covering the phases of Buruburu estate that were developed.

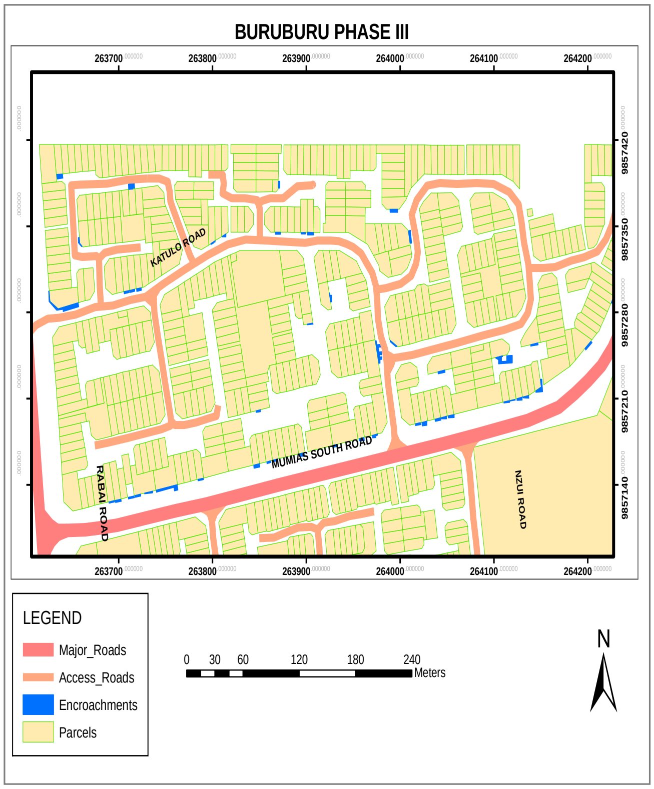

Fig. 16: Encroachment map for phase III

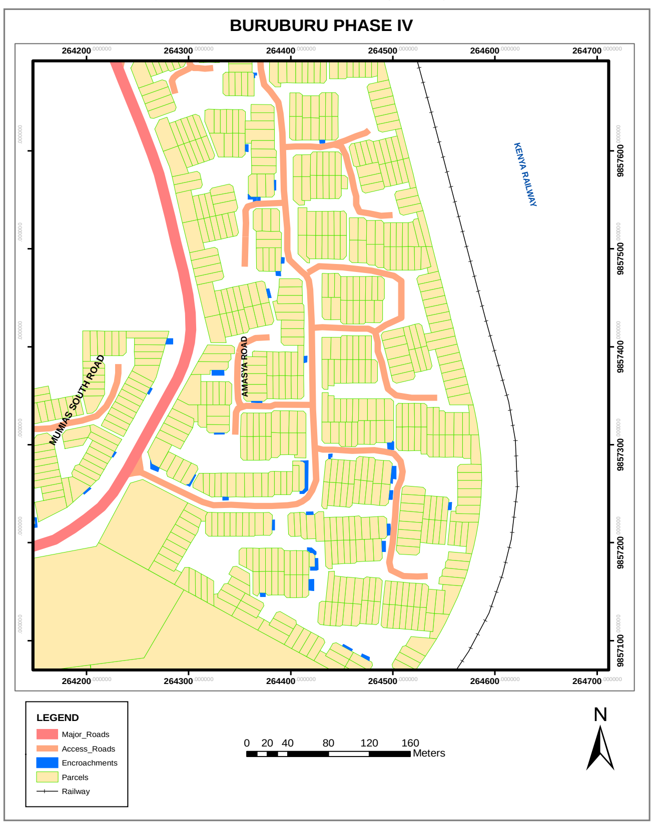

Fig. 17: Encroachment map for phase IV

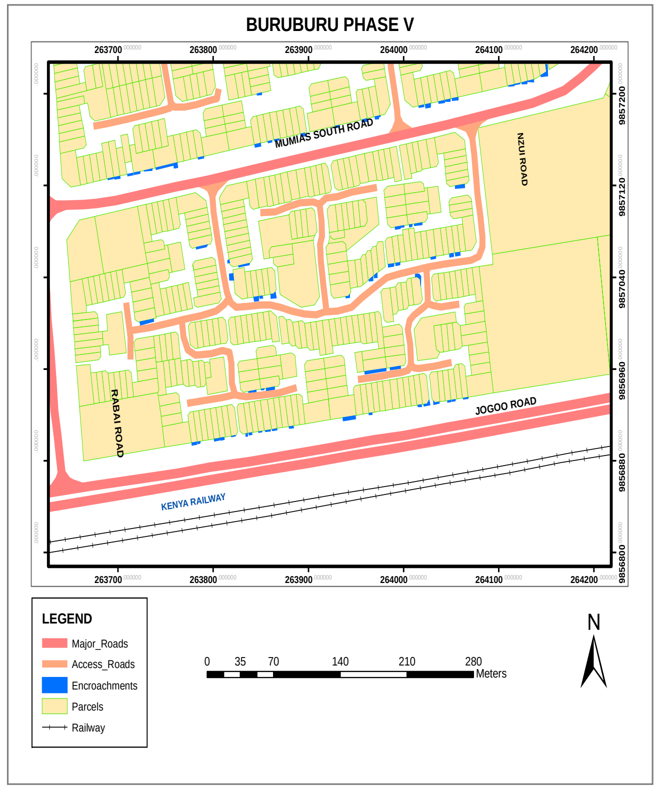

Fig. 18: Encroachment map for phase V

Assessment of Horizontal Accuracy

Spatial Data Accuracy measures how close the recorded location of a spatial feature is to its ground location. This test was done by computing Root Mean Square (RMS) error of a sample of the transformed coordinates and the reference coordinates obtained from the survey plan. The coordinates from the survey plan acts as an independent source of higher accuracy. Calculation of RMS error for horizontal error assessment was obtained from circular error (CE).

$$\text{RMS Error} = \sqrt{\sum\left[\left(x_{data,i} - x_{check,i}\right)^2 + \left(y_{data,i} - y_{check,i}\right)^2\right] / n}$$

Where $x_{data,i}$ and $y_{data,i}$ are the coordinates of the i^{th} check point in the RIM; $x_{check,i}$ and $y_{check,i}$ are the coordinates of the i^{th} check point in the survey plan; n is the number of check points tested; i is an integer ranging from 1 to n. After RMS error was computed, it was multiplied by 1.7308, which represents the standard error of the mean at the 95 % confidence level. The task was done by first identifying the coordinates (UTM coordinates) of 10 common points on RIM and the survey plan. Coordinates from RIM were taken to be measured coordinates while those obtained from the survey plan as the reference coordinates. The RMS error is 0.9582m and horizontal accuracy of transformed coordinates is 1.6584 m at 95% confidence level.

Error Propagation Analysis

The errors that were encountered during the study include: coordinate transformation errors, scanning and tracing errors, digitizing errors, topological errors, georeferencing errors, overlay errors and errors in feature identification on the QuickBird image.

Error sources and estimated quantities

Scanning at 300dpi = ±0.000125 m
Georeferencing errors = ±0.07673 m
Horizontal Accuracy = ±0.9582 m
Digitizing errors:

(a) RIMs: (i) Visible line width = ±0.0002 m
(ii) Zoom scale factor = ±0.5 m

(b) QuickBird Image:
(i) Visible line width = ±0.0002 m
(ii) Feature identification = ±0.61 m
(iii) Zoom scale factor = ±0.5 m

$$\text{Sum Error} = \sqrt{0.000125^2+0.07673^2+0.9582^2+0.0002^2+0.5^2+0.0002^2+0.61^2+0.5^2}$$

Sum Error = **±1.3402 m**

Statistical Test of Mean Areas

The test was carried out by comparing the parcel areas obtained from the ground survey and that obtained from the cadastral database developed so as to assess the accuracy of the results. Data on areas for a sample of parcels obtained by ground survey method and digitizing method was exported to MS excel. The means, variance and standard deviations were computed. Test of means was carried out to establish whether there is a significant difference between the means achieved by the two methods. If so, we could conclude that there is some kind of a systematic error in carrying out the task. The procedure below was followed.

Step I: Mean, Variance and standard deviation for GIS results

Mean $\overline{X}_1$ for perimeter = 98.089 m

Mean $\overline{X}_1$ for area = 0.0219 m^2

Variance for area = 0.4218

Standard deviation for area = 0.6495

Step II: Mean, Variance and standard deviation for ground survey results

Mean $\overline{X}_2$ for perimeter = 98.207 m

Mean $\overline{X}_2$ for area = 0.0205 m^2

Variance for area = 0.4209

Standard deviation for area = 0.6488

Step III: Computation of t

Let μ_1 and μ_2 be the population means estimated by $\overline{X}_1$ and $\overline{X}_2$ respectively. Then the test is:

$$H_o: \mu_1 = \mu_2 \quad \text{OR} \quad H_A: \mu_1 \neq \mu_2$$

If μ_1 and μ_2 are the two sample standard errors and n and n are the sample sizes respectively, then the statistic is given by:

$$t = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{[S^2(^1/n_1 + {}^1/n_2)]}}$$

The statistic given above will have a t-distribution with r degrees of freedom, where $r = n_1 + n_2 - 2$

$$S^2 = \frac{S_1^2\,(n_1-1) + S_2^2\,(n_2-1)}{r}$$

The procedure then is to select the level of significance, α; t is computed from equation above and is compared with the relevant percentile obtained in statistical table. If the computed value of t is greater than the percentile from the table, the null hypothesis is rejected, and if otherwise it is accepted.

$\overline{X}_1 = 0.0219$	$\overline{X}_2 = 0.0205$
$n_1 = 20$	$n_2 = 20$
$S_1 = \pm 0.0062125$	$S_2 = \pm\ 0.00751049$
$S^2 = 6.862745\text{x}10^{-3}$	$r = 38$

Step IV: Comparison of t computed and the value obtained from statistical table

Substituting relevant values in equation 4.3 above,

$$t = 2.040$$

The test is to be performed at 5% significant level, noting that α has to be small for the test to be useful. The percentile in the t-distribution is 2.101, while the computed test statistic, t, is 2.040. Thus the null hypothesis is accepted at this level and a conclusion is made that the difference between X_1 and X_2 is insignificant and therefore the coordinate transformation was correct.

Discussion

Definition of Parcel Boundaries: The type of parcel boundary used in Buruburu estate is fixed boundary. This type of boundary is marked by beacons on the ground and not the features like roads, rivers as it is in the case of general boundary. It becomes difficult for parcel owners to know the exact position of the boundaries of their parcels. This often leads to construction of buildings on the road reserves.

Land Management Database: Cadastral database which is the main objective of this project was finally created. It is from the database that the above results were output. The database brings together most of the parameters needed for the management and inspection of the status of land parcels. Its efficiency is demonstrated in the fact that there is integration of spatial and non-spatial data. The database will therefore support the following:

- Interactive and batch data entry and update
- Querying, reporting and spatial display of the results.
- Thematic representation of information
- Maintenance and decision support
- Land management needs and analysis.

Overlay Operations: Most land parcels in Buruburu estate have illegal extensions. There is therefore a need to come up with a criterion that decision making on which land is maintained. Such could be achieved through overlay. This is done by using QuickBird images covering the area taken in different times for instance after every five years. These images can then be overlaid on parcels layer. This aids in monitoring the status of land parcels as well as the buildings.

Hyperlinking: This feature of linking spatial data to photograph has revolutionized the land condition inspection. In the City Council, most of the land inspection information building plans is stored in form of sketches. The hyperlink feature enables the storage of such information as a picture which is more informative than the inspectional sketches. For instance, it will be easy to evaluate on the way buildings have been constructed on the land parcels.

Conclusions

The main objective of this project was to come up with a complete package methodology that exploits GIS databases and high resolution remotely sensed imagery to analyse road encroachment. Based on the results achieved and analysis done it is concluded that the objectives of the project were adequately achieved. The following conclusions were deduced from the study.

Integration of GIS and Remote Sensing: From the study, it was shown that the GIS and remote sensing application provides users with the ability to view satellite images and cadastral boundaries in a chosen road reserves and to display parcels or houses on the road or houses recently developed as a layer on top. The users can access and assess the information on any parcel such as owner and size and the development status on each parcel. This can incorporate frequent monitoring ensuring that encroachments do not occur.

Role of Cadastral Database in Land Management: The cadastral database will act as a tool for policy makers in matters related to land management. The graphics produced can be adjusted from time to time without enormous costs that are associated with revision of manual databases. Since land transactions are continuous processes, the cadastral database developed demonstrates and provides quick update facilities. For instance, if a parcel is sold, a record on the database is updated as well as its graphics.

Overlay Operations in Mapping Encroachments: Overlay provides addition information on the physical developments on each parcel. This can be done from time to time to assess the parcel status.

Recommendations

Development of Land Information System: From the project, it has been demonstrated that spatial data can be linked with non-spatial data (attribute data) to form a cadastral database. Other information like transportation, utilities, infrastructure and population data can be input in the database to develop a comprehensive LIS. LIS facilitates data sharing and enhances decision making in matters related to land management like rural and urban planning.

Adoption of Unified Coordinate and Land Registration Systems: In Kenya, there are several reference systems used in cadastral surveying. They include: Cassini soldner projection system, War system, Kenya major system, UTM projection system and Local system. The task of coordinate transformation was carried out since the QuickBird image and RIMs were not in the same coordinate system. This was a tedious exercise. Also there are many land registration acts; RIMs are registered under RLA while registration of survey plans is done under RTA. So adoption of a unified coordinate system as well as land registration system is imperative.

Public Sensitization on Boundary Information: Most land owners are not conversant with the boundary information of their parcels. Since fixed boundaries are not described by physical features like general boundaries, it is therefore important that the public is sensitized about boundary information by land experts so that they can know the position of their parcels in relation to the abuttal and the adjoining roads. This will prevent or rather minimize the incidents of encroachments.

Government Compensation: All public land including forests, game reserves and roads belong to the government. In the case of those buildings that have been constructed on road reserves, the owners must compensate the government for using land which is not theirs. The amount of money that the government should be compensated must be accordance with the size of the area encroached. The information on encroached area can be readily obtained demonstrated from the database developed. This will also prevent further encroachments from occurring.

Approval of Development Plans: Most encroachments occur because of using unapproved development plans. This is because of long procedures and modalities taken before the plan is approved. There should be clear policies in Lands Department and the City Council that will govern the procedures taken before the development plans are approved and used.

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