Cadastre Systems and Their Effectiveness in Implementation of a GIS-Based Physical Addressing System:
A Case Study of Kiambu, Thika and Machakos Towns in Kenya

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Abstract
GIS-based physical addressing and cadastre system are inextricably linked. This is because the cadastre shows property boundaries and delimits road reserves that are crucial for an addressing system. The main purpose of this paper is to assess the effectiveness of the cadastre system as a basis for implementation of a GIS-based physical addressing system. A recent physical addressing project for Thika, Kiambu and Machakos towns is used as the case study. Specifically, the paper assesses the adequacy of the existing cadastre, seeks to examine factors that affect adequacy of the cadastre system and proposes strategies for improving the cadastre to support implementation of a GIS-based physical addressing system. The three towns were purposively selected as they were used as pilots for the World Bank – Kenya Government programme that aims towards implementation of a national addressing system. The study used both secondary and primary data sources. The secondary data sources involved assessing the existing analogue cadastre for the three towns. The cadastre was transformed to digital format through geo-referencing and digitization. Observation was used as the primary method to verify the status of physical addressing in the three towns. Additionally, key informant interviews were conducted. The study revealed that the existing cadastre in the three towns was prepared using different scales, have different datum, are incomplete and inadequate, and not current to support a digital physical addressing system. Only the main streets are named and have no unique numbering and naming of properties. The paper concludes that the cadastre systems at their current states in the three towns are not effective as a basis of implementing a GIS-based physical addressing system. The paper recommends an inclusive automation of all cadastre records in the three towns. In addition, there is need to develop a National Spatial Data Infrastructure (NSDI), to support physical addressing.

Keywords: Cadastre, digital, Geographic Information System, land information, physical addressing.

INTRODUCTION

Physical addressing, commonly known as street addressing is an activity that enables spatial location of a parcel or a home/house on land (Farvacque-Vitkovic et al., 2005). Physical addressing is therefore to assign an address by use of maps and signs that give unique numbers or names of streets and buildings (Farvacque-Vitkovic et al., 2005). Property-numbering system makes it easier to find unfamiliar places and lessen confusion (Williams, 2014). Empirical evidence from countries that have implemented physical addressing system point to improved efficiency in urban management, service delivery and economic development (Farvacque-Vitkovic et al., 2005).

GIS analyses spatial location and organizes layers of information into visualizations using maps which reveals deeper insights into data, such as patterns, relationships, and scenarios that inform smarter decisions.

Cadastre is a parcel based, up-to-date land information system containing a record of interests in land such as rights, restrictions and responsibilities. It includes a geometric description of land parcels linked to other records (UN-FIG., 1995). A cadastre is therefore a principal feature in a GIS-based physical addressing system since it records the extent, value and ownership (or other basis for use or occupancy) of land (Farvacque-Vitkovic et al., 2005). The cadastre therefore forms the first layer of base map for the addressing

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system.

This paper aims to investigate effectiveness of the cadastre system as a basis for implementation of a GIS-based physical addressing system using Thika, Kiambu and Machakos towns as the case studies. Specifically, the paper assesses the adequacy of the existing cadastre, examines the factors that affect adequacy of the cadastre system and proposes strategies for improving the cadastre to support implementation of a GIS-based physical addressing system. The three towns were purposively selected as they were used as pilots of World Bank – Kenya Government programme that aims towards implementation of a national addressing system.

THEORY

Williamson, Enemark, Wallace, and Rajabif (2010) provide various land administration principles starting with the land policy as the basis for land management and land law. Land management entails establishment of goals and processes that affect land use in order to achieve expected policy goals (UN, 1996). Land administration includes such processes as determining, recording and disseminating information about land tenure, use, value as well as development (UN, 1996). The cadastral system is therefore a key aspect of land tenure and land administration (Williamson et al., 2010).

The National Land Policy (GoK, 2009) recommend establishment of computerized land information system at the national and local level. The policy further recommends establishment of a national spatial data infrastructure (NDSI) to ensure integration and access of various spatial datasets held by government and private agencies. This would then mean converting existing cadastral datasets into digital format (GoK, 2009).

Various studies have cast doubts on the effectiveness and quality of the cadastre data in Kenya. Njuki (2001) states that the existing cadastre is inadequate since different surveying methods have been used and the resulting cadastral maps have been prepared using different datum and scales. Furthermore, cadastre in its existing form may not be readily feasible in digital automated setting, since different cadastral maps

cannot be spontaneously incorporated to produce a standardized and unified digital cadastre (Siriba, Voß & Mulaku, 2011).

According to Njuki (2001), survey maps should be of sufficient accuracy to support land registration effectively and efficiently. Njuki (2001) further argues that maps are considered suitable for land registration, if they can unambiguously identify on the ground a plot shown on the register, or they can assist in the relocation of a boundary should it be damaged or destroyed. Njuki (2001) indicates that four different types of maps are produced to implement land settlement, consolidation and adjudication programmes. Njuki (2001) correctly argues that survey standards have been compromised in the production of the maps.

The Land Registration Act of 2012, however, envisages a cadastral map that is geo-referenced but also contradicts itself by arguing about fixing of boundaries under section 18, 19 and 20. Under section 19, it appears that the registrar desires the fixing of the boundaries yet they ought to be geo-referenced in the first place (GoK, 2012). Under section 18(1);

Except where, in accordance with section 20, it is noted in the register that the boundaries of a parcel of land have been fixed, the cadastral map and any filed plan shall be deemed to indicate the approximate boundaries and the approximate situation only of the parcel.

However, section 20(1) states;

Every proprietor of land shall maintain in good order the fences, hedges, stones, pillars, beacons, walls and other features that demarcate the boundaries pursuant to the requirement of any written law (GoK, 2012).

Addressing system and cadastre system go hand in hand which spurs interests for an understanding of the cadastre system. The cadastre operates in three types of boundary systems in Kenya: fixed boundary, general boundary and fixed general boundary.

Fixed surveys define high precision boundaries mostly in urban areas. According to survey Act Cap 299, the accuracy required for the demarcation of boundary points for fixed surveys

is ± 2 centimeters. The plan used to represent these surveys is called a survey plan, which upon authentication is used to process deed plans for individual parcels. It has referenced coordinates and description of the beacons. The survey records are kept at survey of Kenya and incase a beacon is lost or tampered with, the same can be accurately replaced. The now repealed Registered Land ACT Cap 300, Laws of Kenya, indicates general boundaries as less precise boundaries defined by physical features such as rivers, streams, trees, rocks, ridges, etc. to demarcate the extent of land. The accuracy of these boundaries is as low as ± 1 meter or even worse. These boundaries are mainly found on large agricultural lands and in most rural areas. The map used for these surveys is called a Registry index Map (RIM) which is prepared from mutation forms. Fixed general survey is a hybrid of the two registration systems. It is an attempt to reference any further alteration on a survey work.

According to Njuki (2001), the low accuracy attained in maps can be attributed among others to the use of unrectified aerial photographs during preparation of the maps. However, Njuki fails to recognize that mutation surveys done during subsequent land administration processes are sometimes not based on scale and their method of survey depends on use of measuring tapes as opposed to higher accuracy survey methods and instruments. In addition, enactment of the Land Registration Act as a substantive land registration Act has weak linkage with the survey Act to warrant guarantee of areas of parcels of land. From the foregoing, the effectiveness of some cadastral maps as reliable tools for physical addressing becomes questionable.

Njuki (2001) concludes that most cadastral maps remain out-dated with delayed amendment of parcels of land, with the currency and accuracy of RIM being the impediment. In addition, maps are stored and retrieved manually making the system inefficient and time consuming. Maps only contain information related to dimensional measurements of a parcel of land and lack information related to, among others, land use and value, vegetation cover, communication, land tenure and utilities (Njuki, 2001).

Background to physical addressing

According to the University of California (UoC) (1992), descriptive addresses have assisted people to find places through references to landmarks such as marketplaces and shrines, among others. Statements such as next to the big tree, around the market, ten steps from the shrine, and so on have been used for many years (UoC, 1992).

Modern addressing system commenced in Western Europe and United States in the 18th century (UoC, 1992). In the 20th century, implementation of physical address networks advanced beyond the mere facilitation of communication and organization to provide the base for social and economic development (The UoC, 1992). West-African countries such as Ghana, Burkina Faso, Mali, Senegal, Togo and Cameroon, were the first to introduce addressing in Africa in the mid-1980s. (Abebrese, 2019). Implementation was done in main cities, while street numbers were implemented in zones surrounding the cities (hinterlands). However, most of rural areas were neglected. After independence, this system fell into disuse since there was no proper transition and awareness creation to the system (Farvacque-Vitkovic et al., 2005). To date, largely, there is a new wave of awareness about the importance of physical addresses.

Physical addressing in Kenya was first rolled out in the central business district of Nairobi. The Works and Town Planning Committee of 9th August 1989 resolved that all properties in the City shall have a street number. According to City of Nairobi general nuisance By-laws 1948 - section VIII, No. 426;

Every owner or occupier of a home or building to affix to the front door or gate of such a house or building a plate bearing such number in conspicuous figure within a time to be specified.

However, because of rapid post-independence city expansion beyond the original fixed urban space, spontaneous residential developments have grown and developed without any urban planning or visionary design to its street layout, devoid of official street naming and house numbering.

In 2012, a comprehensive addressing system was rolled out in Nairobi City County by the Government of Kenya in collaboration with

the World Bank. The objective of the addressing system was to make it possible for tax collection, statistical requirements, safety and security service, social services (CAK, 2016). The second compressive physical addressing system was rolled out in 2016 for three towns namely: Thika, Kiambu and Machakos towns. As part of Nairobi Metropolitan Services Improvement Project (NaMSIP), the Government of Kenya received financing through World Bank.

In 2018, the lands ministry was expected to roll out new Land Information Management System (LIMS) but the process has taken too long to implement. Since then, only the preliminary stages on development of the LIMS have been partially implemented. LIMS has been singled out as a land-based project milestone for Kenya Vision 2030 that targets to establish a transparent, devolved, affordable and efficient GIS-based Land Information Management System.

Approaches to a GIS-based physical addressing system

Farvacque-Vitkovic et al. (2005) outline the methodology of developing a GIS-based physical addressing database in three key chronological phases. The first phase entails preparation of an up-to-date GIS base map; street codification and addressing physical properties. Primary features of a GIS-based physical addressing basemap are road centrelines, digital cadastral layer and footprints of all properties. It also entails development of addressing localities and associated attributes such as land use, number of floors and so on. (Farvacque-Vitkovic et al., 2005).

The second phase involves street codification. Codification entails assigning unique codes to streets irrespective of whether they have names or not. It is based on the positioning of street segments. As principle, it is assumed that streets typically adopt North-South direction (N-S) or West-East (W-E) orientation. N-S streets are assigned odd numbers in relation to the selected reference axis. W-E streets are assigned even number in relation to each respective N-S street that they emanate from (Farvacque-Vitkovic et al., 2005).

The first step in codification requires developing a reference point known as point zero where all streets confirm/start numbering increasing gradually. Start and end point of every street must also be defined with correct orientation from the reference point (Farvacque-Vitkovic et al., 2005). The second step, involves classifying the developed streets centrelines according to North-South direction (N-S) or West-East (W-E) orientation. Lastly, unique identifiers are allocated to the streets (Farvacque-Vitkovic, et. al., 2005). The third phase involves addressing physical properties. This involves orderly unique numbering of properties/buildings in a system that is simple, clear and easily understandable by target users (Farvacque-Vitkovic et al., 2005).
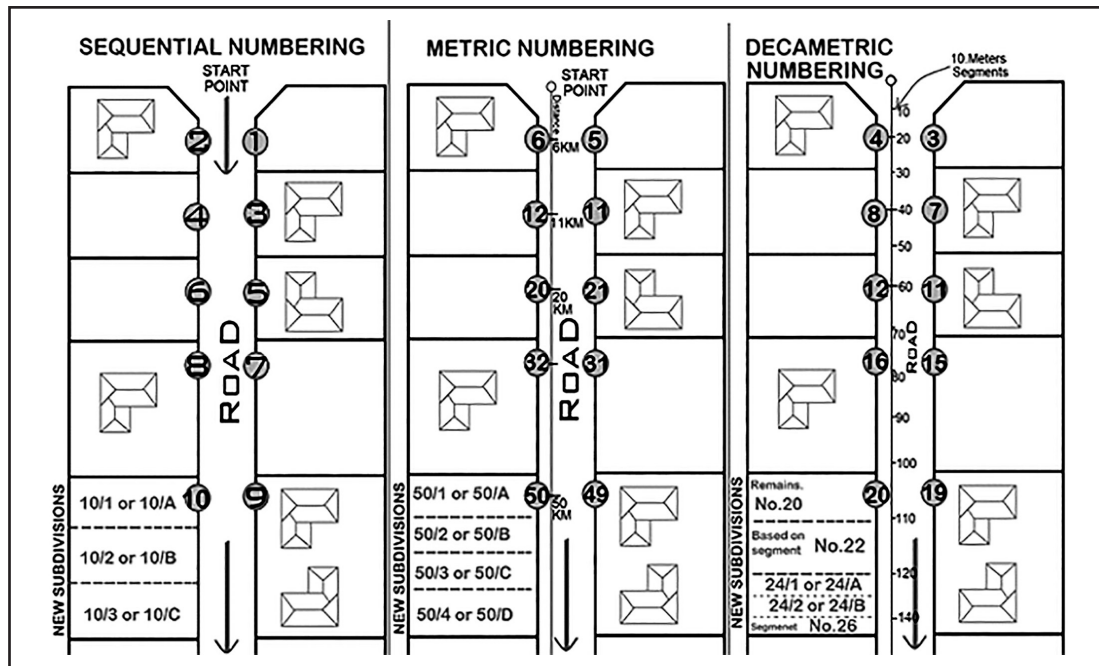
Systems of property addressing

There are three main property addressing systems that are universally applied in physical addressing. The first one is called sequential numbering. This system subscribes to numbering existing properties in a continuous order. For instance, 2, 4, 6, etc. – on the right side and 1, 3, 5, etc. on the left side.

Metric numbering is the second system. Within this system, properties are numbered compliant to their distance from the start point of a street. Distance is literally measured and figures are rounded up or down to the closest even or odd figure depending on the side of the street.

Lastly, is the decametric numbering system which ensures even and odd numbers are allocated chronologically, but according to 10-meter-long sections of the street. This is a negotiation between the sequential and metric systems hence offering double advantage of simplicity and clarity in predictable distance numbering (Farvacque-Vitkovic et al., 2005). **Figure 1** illustrates the systems of property addressing.

RESEARCH METHODS

This paper was prepared based on experiences of the authors being part of the team tasked with implementation of physical addressing system in Kiambu, Thika and Machakos towns. The main objective of this research was to investigate effectiveness of the cadastre system in implementation of a GIS-based physical addressing system.
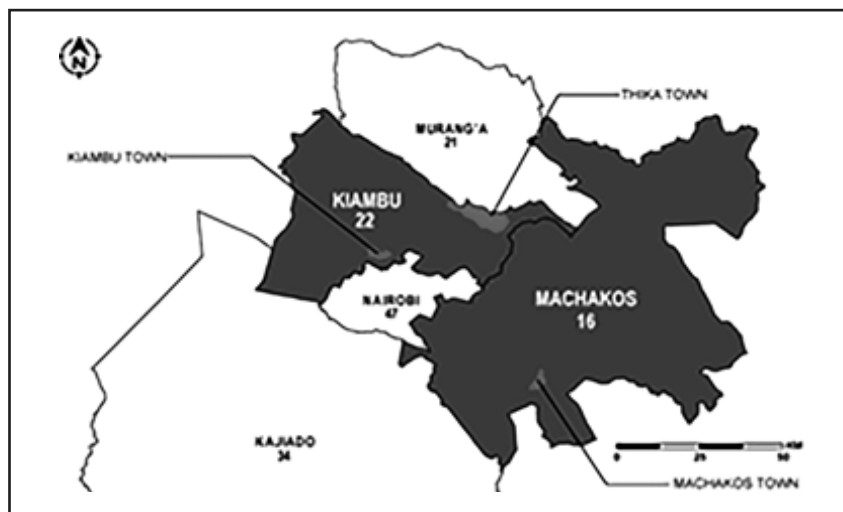
FIGURE 1
Illustrations of systems for addressing properties
Source: Authors 2019

Secondary sources were the main source of data for the study. During preparation of the addressing basemaps for the three towns, cadastre was only available in paper sheets. This necessitated transformation from its current state to digital GIS vector format. Registry Index maps (RIMs) were sourced from Survey of Kenya. The first step entailed scanning and geo-referencing the RIM sheets followed by digitization, populating attributes and spatial adjustments/cleaning of

the resulting parcels to develop a digital cadastre layer. **Figure 2** shows the location map showing the study sites within their respective counties.

The main primary method of data collection was through observation. This was done through field visits to observe and verify status of physical addressing available in the three towns. Interviews with key informants, including county planners and administrators, in the three towns were

FIGURE 2
Location of study areas
Source: Groupe Huit 2017

conducted. Various stakeholder consultative meetings with the client, World Bank officials and the technical working groups (TWGs) in the three towns were also held. Additionally, point data of important landmarks were picked using hand-held GPS (Global Positioning System) and incorporated in the basemap layer.

RESULTS AND DISCUSSION

Status of physical addressing in the three towns

Physical addressing in the study areas is incomplete. Contrary to explanation by Farvacque-Vitkovic et al. (2005), where addressing ought to assign unique numbers/names of both streets and buildings, the status of addressing in the three towns only involved naming of the main streets and roads. There were no unique given numbers on buildings and properties. There is still over reliance on descriptive addresses which is time consuming. **Figure 3** is a sample of street addressing along Kenyatta Highway in Thika Town (double naming of a street).

Adequacy of the existing cadastre

Several factors were used to assess the adequacy of the existing cadastral information as the basis for the development of a GIS-based physical address system in the three towns.

Data format

Existing cadastral data was in hardcopy sheets of RIMs and survey plans representing general boundary and fixed boundary systems respectively. This required further processing to digital format through scanning, geo-referencing and digitizing using GIS software to fit user's needs.

Primarily, the fixed boundary covered CBD area of Machakos and Kiambu towns while general boundaries covered other abutting areas. The cadastre only represented property boundaries but did not record important land marks such as rivers, forest etc. Moreover, the cadastre did not record important attribute information such as owners' details and landuse which are important in the addressing system.

This is in agreement with Njuki (2001), who indicated that survey plans and RIMs only show boundaries of properties. **Table 1** is a summary of the cadastre status for the three towns.

Coordinate system used

The study revealed that different coordinate systems were used within the same locality. This automatically creates conflicts between datum coordinate system and methods of survey used. Fixed surveys are not related to mutations and RIMs. The three towns exhibited a high level of warps and shifts in the digitized cadastre layer (shapefile) compared to the situation on the ground. These were as a result of use of Cassini and other coordinate systems from the geo-referenced cadastre sheets. To solve these issues, otho-rectified aerial image, transformation of coordinate systems to a single uniform system as well as performing spatial adjustments on the warps using ArcGIS software so as to match features and existing boundaries on the image.

Accuracy– size and shape, orientation, scale, road centreline

Conflicts between the roads provided in the cadastral layer and the existing aerial image were

FIGURE 3
Sample of street addressing along Kenyatta Highway in Thika Town
Source: Google street view 2018

TABLE 1: Summary of cadastre status for the three towns

Town	% of fixed survey cadastre available	% of general survey cadastre available	Main cadastre issues presented
Machakos	30% of the study area. Only available in CBD	70% of the study area. Hinterland predominantly rural	Organic cadastre layer, Distortion, Different scales and coordinate systems used on cadastre sheets available
Thika	85% of the study area	10% of the study area. 5% completely missing (holes)	Missing data. Inconsistencies between the cadastre and existing road system properties exceeding their cadastral boundaries
Kiambu	23% of the study area. Only available in CBD	56% of the study area. 5% completely missing (holes)	Missing data. Duplicate parcel numbers, Multiple parcel numbers, Missing parcel numbers

Source: Author 2019

noted. In all the towns several roads cut through parcels indicated in the cadastre. The converse was also true where roads failed to exist in areas that the cadastre had provided for them (**Figures 4**, **5** and **6**). Some properties were also noted to exceed their expected boundary and as a result blocked expected road. Upon further investigations, it was discovered that this was caused by warps as a result of digitization/transformation and, road user preferences where informal roads/access footpaths were created across undeveloped plots/parcels due to missing links or long distances covered when using official designated roads. Ortho-rectified aerial image was used to clean the cadastre layer and street centrelines for sole purpose of developing a GIS-based street addressing database.

There were instances in Kiambu and Machakos where the parcels were organic/irregular or narrow. These configurations do not provide adequate control points to do the spatial adjustments for the parcels for development of GIS-based physical address database. **Figures 7** and **8** illustrate the irregular plots as they appeared on the cadastre.

Ground verification found out that the narrow parcels were as a result of existing features and their associated advantages. For instance, narrow plots in Kiambu town were as a result of plots being in between a river and a tarmacked access road. Organic parcels were as a result of the use of cadastre layer digitized from general survey boundaries. This provided challenges in the initial

stages. However, an anticlockwise spiral system of numbering/coding was used from point of reference, to allow room for expanding the system further to the rural hinterland in the event the town boundaries expands in future.

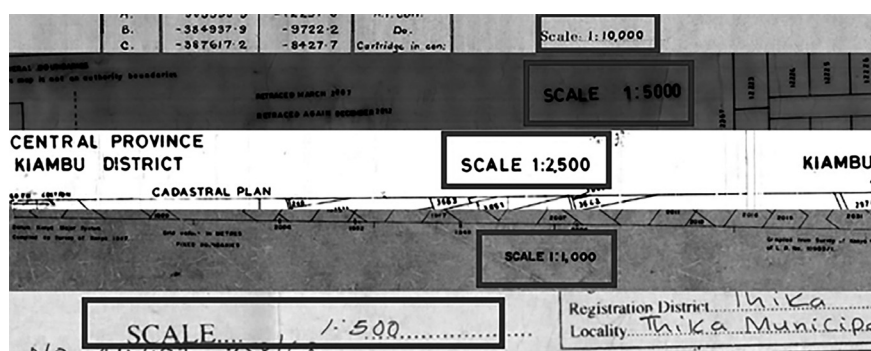**Completeness (missing plots, plot numbers, holes in the cadastral maps)**

Some sections in the study area didn't have cadastral records and boundary demarcations. This displayed sections without parcels in the maps (holes). Ground verification found out that some of these areas were informal settlements. Otho-rectified image was used to digitize observable property boundaries. Ground-truthing was used to verify the digitized information. However, additional sections with holes in the cadastre data were as a result of survey that was done but was either pending approval or has never been submitted to the survey registry for updating.

Overlaps (double allocation of numbers, parcels with multiple numbers within the same block)
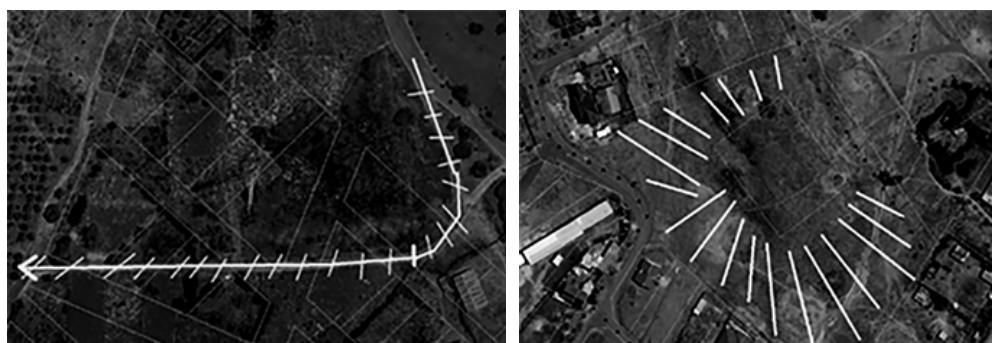
Some areas especially in Kiambu exhibited a number of duplicate parcel numbers where one parcel number was used in more than once in the same RIM sheet. This was more evident in Ndumberi registration block of Kiambu Township (**Figure 9**). Some parcels also exhibited the peculiar case of having more than one parcel number both displayed in the same parcel in the RIM (**Figure 10**). Moreover, a sample of properties had missing plot numbers either due to an omission in the

FIGURE 4
Sample of inconsistencies found when cadastre layer was overlaid on an Ortho-rectified image
Source: Cadastre digitized from Survey of Kenya RIMs 2017

FIGURE 5
Screenshot sampling different scales used to prepare cadastre information within study areas
Source: Survey of Kenya 2017

FIGURE 6
Roads cutting through properties while others missing in totality
Source: Cadastre digitized from Survey of Kenya RIMs 2017

records or the numbers not being legible in the RIM sheets.

Legally, the survey registry is authoritative source of cadastre information. The study had no authority to make changes on the information. However, a different layer for these parcels was digitized to create unique identifiers for the purpose of assigning addresses.

Factors that affect adequacy of the cadastre
Resources

The three-town exhibited shortage in technical capacity, technology, space and capital. There was no significant County budgetary allocation towards maintenance and storage of cadastre information. The situation is similar to the national survey registry where all cadastre information was retrieved. This has resulted to inefficiency and time waste which relates to Njuki

FIGURE 7
Organic parcel configurations in Machakos Town
Source: Cadastre digitized from Survey of Kenya RIMs
2017

FIGURE 8
Narrow parcel configurations in Kiambu Town
Source: Cadastre digitized from Survey of Kenya RIMs
2017

FIGURE 10
Illustration showing parcels having more than one
number
Source: Cadastre digitized from Survey of Kenya RIMs
2017

(2001), who notes that cadastre maps are retrieved manually making the system inefficient and time consuming.

Accessibility to data

It was established that, a written permission from the Director of Survey was required if one required cadastre information exceeding five sheets. This written permission was to be accorded upon submission and approval of justification as to why the cadastre information was required. A sheet of cadastre information could only cover about 2% of the study area. Cadastre information that could be sourced from respective County Lands Office still required verification from Survey of Kenya. These encounters are contrary to the provisions of the Kenyan Constitution. Under Article 35, every citizen has the right to access information held by the State or by another person and required for the exercise or protection of another right (GoK, 2010). Access to cadastre information is a challenge.
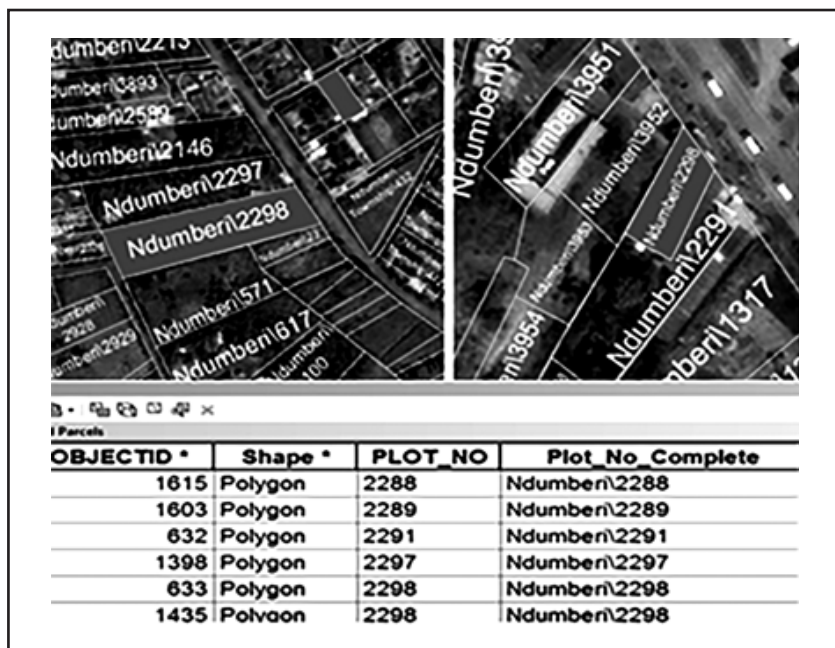
Cost of data

The cadastre sheets were purchased at Survey of Kenya. Additional cost was incurred in printing and scanning of the sheets. Additionally, geo-referencing and digitization are processes that required employment of technicians to assist with the transformations. All these associated costs also present additional access and adequacy challenge.
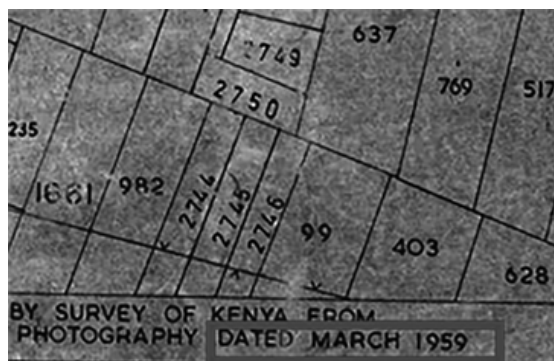
Currency of data- obsolete out-dated

Cadastre from RIMs covered majority of the required information for the study area. However, this data was found to be obsolete. Some were prepared in 1959 even before Kenya attained independence. It is more worrying since it is the only verifiable data. Ground verification further established major shifts from what is presented on the map versus what is on the ground. **Figure 11** is an illustration of a cadastral map that was drawn in 1959.

Poor data storage techniques

Cadastre was found to be stored in cabinets and files. The data has been stored in this state for many years (some since pre-independence). These storage techniques resulted to damage of information. A number of cadastre sheets were

FIGURE 9
Illustration showing the two parcels with similar plot numbers
Source: Cadastre digitized from Survey of Kenya RIMs 2017

FIGURE 11
Sample of cadastre information in Thika town dated 1959
Source: Survey of Kenya 1959

found to be torn, warped and ineligible.

CONCLUSION

The cadastre system is not effective as a tool for implementation of a GIS-based physical addressing system in Thika, Kiambu and Machakos towns. This is because the cadastre system is not automated and conforms to the manual out-dated system where data can only be found on sheets of paper. The cadastre also has limitations of not showing any other detail apart from the property boundaries and plot numbers. Associated attributes such as ownership details, landuse and so on, which are vital in development of a GIS-based physical addressing system are missing.

The towns used as case studies are towns in the Nairobi Metropolitan Region. However, the cadastre in these towns still cast doubts on the quality and currency of the information. This is a clear indication that computerization and automation of cadastre is not viable unless necessary planning and survey measures are taken to capture important land-based attributes. In its existing form, the cadastre system is not adequate for a land information system in the study area. This implies that any new project that would require digital cadastre must start with the process of digitization from the hard copies.

RECOMMENDATIONS

Existing cadastral data which was used in the project was found to have various gaps that require quick attention. The paper recommends cleaning, updating and automation of cadastre and all other land information in the three towns. It further recommends the county and national government to avail resources including technical capacity, technology and finances.

There is need to ensure preparation and implementation of national spatial data infrastructure (NSDI) Policy in Kenya. The NSDI will bring together series of agreements on technology, standards, institutional arrangements, and policies that enable the discovery and use of spatial information by users. With NSDI, land information will be efficiently made available for timely decision making.

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