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Development Of A New Cadastral Model For Kenya

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Abstract: ***The Cadastral system in Kenya was established in 1903 to support land alienation for the white settlers who had come into the country in latter part of the 20th Century. In the last hundred years, the system has remained more or less the same, where land records are kept in paper format and majority of operations are carried out on a manual basis. The lack of a modern cadastral system has contributed to problems in land planning, access and administration.***

The Government has expressed the need to modernize the system in order to facilitate better land administration, support the development of an integrated Land Information Management System and a National Spatial Data Infrastructure. However, one persistent denominator to these efforts has been the lack of a modern cadastral model.

This paper discusses a recent study carried out in Kenya to provide solution to the problem by developing a new cadastral model, based on a Object-Relational Model. In carrying out the study, user needs assessment was carried out to support conceptual and logical design of the new cadastral database. In implementing the model, a conceptual/logical model was developed based on Multi-Value Vector Maps and Smiths Normalization procedures. The resulting Functional Dependency Diagrams were used to design tables for subsequent querying with Microsoft SQL Language.

Results from the study indicated that Smiths Normalization and Functional Dependency Diagrams are suitable for the automatic generation of fully Normalized Tables and a successful query of and displayed of multi-parcel ownership. On the other hand, it has been observed by various authors that typical Cod Normalization procedures do not support the display of multi-parcel ownership and automatic production of fully Normalized tables.

Keywords: ***Object-Relational Database Modelling, Functional Dependency Diagrams, Smiths Normalization.***

I. INTRODUCTION

The need for modern cadastre has been a major concern of the United Nations since its inception. In 1972, the UN called together an ad-hoc group of experts to study the problems of cadastral surveying in developing countries and to consider setting up a permanent committee to constantly review the developments in this area, [UN-FIG, 1996]. Further commitments to these reforms were demonstrated in the Agenda 21 [UN-FIG, 1998] and the Habitat II Global Plan of Action [UNCHS, 1996]. At these meetings, it was recognised that efficient and effective cadastral systems are essential for economic development, environmental management and social stability in both developed and developing countries.

Today, what is emerging is that many countries in the West have moved from the traditional cadastre to modern multi-purpose cadastre where information about resources, land use planning, land value and land titles, including individual and indigenous rights, are integrated into a single geospatial database for effective utilization [Williamson, 2000: 13]. In majority of these countries, land registries have been modified to include coded building information (in both 2D and 3D) and utilities, and land information systems are already web-based.

In Africa, however, many countries are still stuck in the old traditional systems where majority of cadastral operations are in paper format and the processes are manual-based. While these traditional systems were well suited for the simple agrarian societies, the sophisticated economies of the 21st century need the services of modern cadastre to effectively deliver the objectives of sustainable development. Stand-alone approaches that supported individual purposes are no longer sustainable.

II. THE KENYAN SITUATION

In Kenya, the Ministry of Lands plays an important role in the achievements of the aspirations of vision 2030 and land reforms have been identified as one of the foundations upon which economic, social and political pillars of Vision 2030 are anchored. Vision 2030 envisages that land reforms involve the modification or replacement of existing institutional arrangements governing possession and use of land in order to improve land administration [*wikipedia.org/wiki/Land reform*]. Already the government of Kenya has fulfilled some of these objectives by enacting new Laws and regulations governing land. These include the National Land Commission, Land Act, and Land Registration Act among others.

These reforms are aimed at improving access to land and ensuring better utilization of the natural resources. The Ministry appreciates that the transformation envisaged under Vision 2030 must be anchored on strong policies and legal-institutional framework such as already entrenched in Chapter Five of the Kenya Constitution, 2010.

The achievement of these noble goals requires an integrated approach to land development and an efficient land market. To this extent, Agenda 21 [UN-FIG, 1998] already recognised that the integrated approach to land development is one of the most important denominators to delivering the objectives of sustainable development in the 21st century. If Kenya has to achieve the objectives of sustainable development and Vision 2030, the government needs to embark immediately on a programme of modernization of the cadastral system as this is the spatial framework which supports the implementation of such development agenda.

The Ministry of Lands, in its Strategic Plan (2008-2012) and performance contract (2010/2011) already identified that to ensure effective and efficient service delivery to the clients; processes, procedures and practices of handling land information need to be re-designed. It further noted that such re-design should include, Business Process Re-Engineering, and targeted four bench-marking activities towards achieving these objectives. These four bench-mark activities included a review and documentation of current processes, procedures and practices; redesigning procedures and processes of land administration; making recommendations for quick-win projects; and implementation of a National Land Information System [MoL, 2011: 17].

This study was therefore carried out in a representative study site around the city of Nairobi to develop a modern cadastre model for Kenya based on Object-Relational Model with a spatial datasets directly accessible in the ArcGIS software.

III. THE OBJECT-RELATIONAL MODEL

Under the Object-Relational Model, a Functional Dependency Diagram was developed based on the Multi-Value Vector Maps criteria, and Smiths Normalization procedure was used to produce fully Normalized Tables [Fig.1.2]. These tables were populated with datasets picked from the user needs assessment and the prior knowledge of the structure of the Kenya cadastre. The spatial dataset consisted of a digital cadastral map of 628 plots projected onto the UTM grid; although only forty plots were selected for the database development [Fig.1.3].

The tables which were developed mainly consisted of; parcel ownerships, deed plan numbers, Folio Registry (FR) Numbers, Personal Identification Numbers (PIN) for each parcel owner, and encumbrances on any of the parcels. Other information included; Name of Surveyor, Computation Sheet Number, File Number and acreage of each parcel. A few examples of the tables are presented in the appendix.

In Kenya, the cadastral system still based on the paper format where the Folio Registry Number (FR-Number) is the main entry point into the cadastre. Each cadastral plan is designated a unique FR Number which describes the entire sheet. On each map there may be one or more parcels designated with parcel Number or Land Registry Number. In this study, the study case is based on a title registration system, the Registration of Titles Act (RTA, Cap 281 of 1915) hence all the parcels bear the LR Numbers. This number is important as it is quoted in all documents concerned with the land parcel, including the title document and is therefore an important data set in the new cadastral model.

Apart from the FR and LR numbers, the cadastral plan also shows the layout of all land parcels and their attributes such as area, coordinates, type of the beacons, bearings of land parcels, name of the surveyor, computation and file number. The plan also indicates the date of authentication and name of the authenticator, the history of the parcel numbers from the previous surveys and how the numbers have changed over time. All these information are shown in Figure 1.4 showing an example of a Kenyan authenticated cadastral plan.

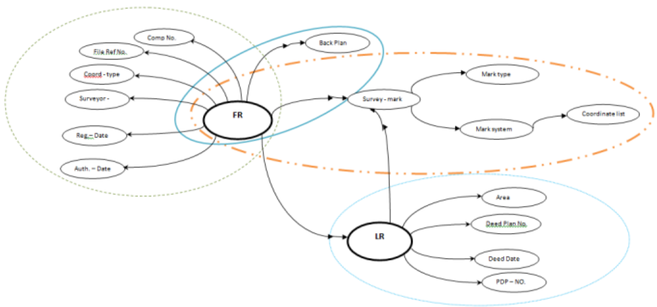

Figure 1.1: Functional Dependency Diagram (Source: Own Figure)

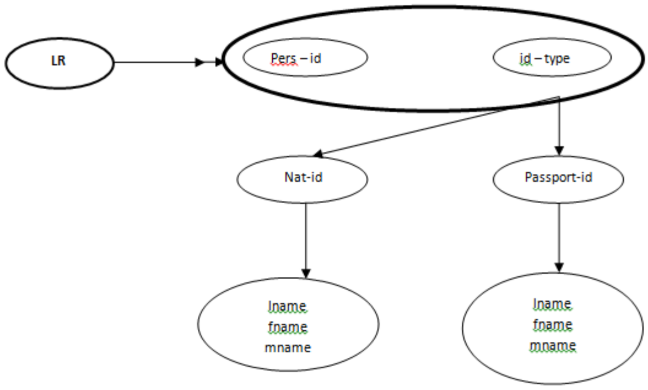

Figure 1.2: Functional Dependency Diagram for Parcel Ownership

LR	PERS_ID	ID_TYPE

Table 1.1: Parcels Ownership

PERS_ID	ID_SW	NAT_ID	L_NAME	F_NAME	M_NAME

Table 1.2: National Identification Card

PERS_ID	ID_SW	PASSPORT	L_NAME	F_NAME	M_NAME

Table 1.3: Personal Passports

LR No	PIN No

Table 1.4: Kenya Revenue Authority Tax PIN Numbers

FR	BACK-PLANS

Table 1.5: Back Plans Table (The Abutting Plans)

SURVEY MARK TABLE

A survey plan has a coordinate list of all survey marks, each mark identified by SURV - mark (string) and every survey mark has a type identifier MARK – type (type numeric). Each survey mark has a unique set of coordinates in a given coordinate system MARK – SYS. A survey mark may therefore be indentified in one of more coordinate systems. The survey mark table uses the F/R No., the LR as the Primary Keys. Fully populated Survey Mark Table is shown in the Appendix 8.

FR	LR	SURV_MARK	MARK_TYPE	MARK_SYS

Table 1.6: Survey Mark Table

SURVEYOR TABLE

A survey plan has an identifier Folio Register Number (the FR) (type string) and has one or more parcels each having a unique parcel identifier Land Registry Number the LR (type string). The survey plan has the surveyor's identification number, surveyor_ id (type numeric), having a national identification card number Nat_id (numeric), Computations Number (numeric), the registration date REG-date (type date) of which the plan was registered by the Director of Surveys and authentication AUTH-date (type date) on which the survey was found acceptable and authenticated by the Director of Surveys. The plan also has a coordinate projection identifier COORD-TYPE (type numeric) which indicates the system upon which the survey was carried out.

FR_No	SUR_ID	REG_DATE	AUTH_DATE	COOD_YTPE	COM-N	F_N	F-B

Table 1.7: Names of Surveyors

IV. TRANSFORMATION OF COORDINATES

The cadastral data used in this study were obtained in hard copy format from the Department of Surveys. The data consisted of six authenticated cadastral plans with coordinates in Cassini-Soldner projection. In total, there were six Folio/ Registration sheets containing a total of 628 plots. Forty plots from the scheme were chosen for the development of the cadastral database. These parcels were contained in plans covered by F/R Nos.339/32 and F/R 333/29. In order to acquire soft copy of the cadastral data, the plans were digitized with the ArcGIS software and co-registered with the orthophoto imagery.

Transformation equations were used to determine four transformation parameters (two translations in N and E directions, a uniform scale factor and one rotation angle) to convert the Cassini coordinates into the UTM (1960 Arc Datum) coordinates system. This was necessary to provide compatibility between the cadastral plan coordinates and the GIS system. Generally, GIS systems operate in the UTM while the cadastral plans in Kenya are on the Cassini system.

A network of four triangulation control points: SKP208 (LAMUIA), SKP216 (SAPUK), 148S4 (MARULAIS) and 149S3 (LUKENYA) with coordinates in both Cassini and UTM systems were used to derive the parameters. The datum coordinates of the stations selected are presented in Table 1.8.

Station Codes	Names of Stations	1960 Arc Datum UTM Coordinates		Cassini-Soldner Coordinates	
SKP 208	LAMUIA	9,843,205. 25	237,160. 30	-156,927.59	-40,380.73
SKP 216	OLDONYO	9,874,247.920	306,011.96	-125,946. 38	+28,474. 84
148S4	MARULA	9,864,732.064	267,906.11	-135,431.75	-9,629.97
149S3	LUKENYA	9,837592.79	284,419.10	-162,578. 03	+6,855.62

Table 1.8: List of Datum Coordinates (Source: Survey of Kenya, Ruaraka)

V. RESULTS AND DISCUSSION OF RESULTS

The results obtained from the modeling exercise are presented in this section. These include; the transformation parameters and the UTM (1960 ArcDatum) coordinates, and several attribute from querying the Relational tables and the spatial database through the ArcGIS software.

FR	LR	L_NAME	F_NAME	M_NAME
339/32	26699/898	TANUI	JOSEPH	KIBET
339/32	26699/898	KIBET	ANNE	KAREGI
339/32	26699/900	MACHAYO	JOAN	ANDISI
339/32	26699/899	MACHAYO	JOAN	ANDISI
339/32	26699/897	MOSAISI	FLORENCE	BONANERI
339/32	26699/961	MAINA	GERALD	IRUNGU
339/32	26699/962	MAINA	GERALD	IRUNGU
339/32	26699/947	GICHIA	PAUL	KIBITHE
339/32	26699/948	GICHIA	PAUL	KIBITHE
339/32	26699/960	ANDAYI	FRANCIS	WECHE
339/32	26699/925	OBIYE	JOHN	ISAAC
339/32	26699/952	MULUMBA	SIMON PETER	KASANGA
339/32	26699/916	OKUNYO	GORDON	ONYANGO
339/32	26699/917	MAKOYUGI	GEORGE	W.O.
339/32	26699/912	KIBA	MARGARET	WANGARI
339/32	26699/906	KITUR	EMILY	
339/32	26699/902	KOYENGO	GLADYS	OKAKAH
339/32	26699/902	KOYENGO	LORRAINE	AKINYI
339/32	26699/939	WARUI	WINNIE	WANGARE

339/32	26699/946	NZEKA	QUEEN	TENDALOIN
339/32	26699/932	MURIITHI	ISABELLA	NGIRA
339/32	26699/958	MUTUKU	RUTH	MULEE
339/29	26699/604	OMONDI	TOM	ONYANGO
339/29	26699/604	OKOTH	EVALYN	ADOYO
339/29	26699/600	OKACH	DAVID	OCHIENG
339/29	26699/965	OYARE	POLYCAP	ODHIAMBO
339/29	26699/494	TALLAM	MARGARET	J.
339/29	26699/473	ADAMBA	JULIA	ASEYO
339/29	26699/475	ILAMBO	MARY	ATAMBA
339/29	26699/490	KARIUKI	MICHAEL	NJENGA
339/29	26699/479	WAKA	REBECCA	KAGEHA
339/29	26699/599	OTIN	JOSEPH	MUSITA
339/29	26699/528	MASAMBU	RUTH	WABAFU
339/29	26699/510	AGUTU	DICKSON	OKUMU
339/29	26699/501	ODANGA	ESTHER	DAMAR
339/29	26699/519	AHOMO	JOSEPH	MUGWANGA
339/29	26699/658	MUTINDA	CATHERINE	M.
339/29	26699/658	MUSYOKI	HUDSON	N.
339/29	26699/557	ASANGA	DANIEL	CHEPKWONY
339/29	26699/540	RUKUNGU	HILDA	WAIRIMU
339/29	26699/547	ABELE	MILDRED	
339/29	26699/613	NDENGA	SOLOMON	KILAHA
339/29	26699/859	OKIL	STEPHEN	OCHIENG
339/29	26699/984	KAHUKI	STEPHEN	KAMAU
339/29	26699/984	KAHUKI	SHEILA	KAWIRA

Table 1.9: A populated parcels Ownership Table

In order to develop a modern cadastral model, it was necessary to convert all coordinates from Cassini into the UTM system so as to have all the spatial data compatible with the GIS software systems. The results presented in Table 5.8 and indicate that; a four parameter transformation is adequate for derivation of the transformation parameters required for cadastral mapping. The map shown in Figure 5.14 is the result of the plots that were digitized from the transformed coordinates and saved as part of the spatial database. Some of the challenges noted in this process were that; it is difficult to obtain points with both Cassini and UTM coordinate systems as most of the old survey monuments have been destroyed, the records at the Survey Department are not kept up-to-date hence the reliability of the coordinates data is doubtful, and there are several cadastral coordinate systems in Kenya and selecting the right coordinates for transformation can be confusing.

Parameter	**Value**	**Accuracy**	**Units**
S	1.0000169	±0.000002	-
θ	-0.000886	±0.000002	rad
ΔN	10,000,167.51	±0.35	m
ΔE	277,419.49	±0.35	m

Table 1.10: Four Transformation Parameters

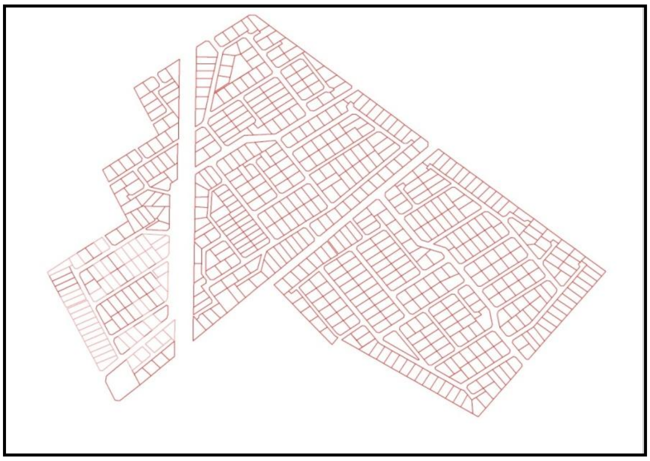

Figure 1.6: Digitized Cadastral Plan of the study Area (Source: Field Work)

Figure 1.7: Cadastral boundaries on ortho-rectified aerial photograph of study Area

VI. CADASTRAL MODEL QUERY OPERATIONS

The hybrid system is supported by a robust GinisNT and Mediator systems which interfaces the operation between the OODBMS and the RDBMS. While the purely RDBMS relies on joins for query developments, the hybrid system uses relates to access information in both databases, which is particularly suitable where spatial data analyses are concerned. In this study, for example, the spatial data are kept in the GIS database while all the other relational tables are kept in an RDBMS such as excel software. The relational tables implemented in the Excel are presented in Appendices 3-8. Without adopting the hybrid system, it would have been difficult to query the spatial data as typical join operations tend to de-normalize the tables.

The queries were constructed via the SQL module in the ArcGIS system. Once the RELATES were established between the OODBMS and the RDBMS, queries were built using the SQL module within the ArcGIS environment. In this study, the queries such as LABELLING and SELECT were implemented on the cadastral plan via the GinisNT procedure explained above. For the M:1 relationships, a special computer programme was developed to select the parcels with multiple ownership (Tables 5.11and 5.16).

The process of labelling involves querying the computer to display certain labelling commands. The computer may, for example, be requested to label all the built-up plots in the study area. By using the label command, all the developed plots are labelled and the non-developed ones are left vacant. In this study, several labelling queries were implemented as shown below.

In Table 5.9 the Labelling query was used to show the PIN number of the plot owners onto the cadastral plan held in the GIS database. This was accomplished by the user requesting to be shown the PIN Number of the chosen parcels in the study area. This is a facility which would be useful to the Kenya Revenue Authority and the Local Authorities when they want to identify plot owners and track whether they have paid the requisite taxes; particularly land rent, land rates and stamp duty on transfer of plots.

PIN Number is important to the Kenya Revenue Authority (KRA) as it is associated with the taxation process. At the moment, the Commissioner of KRA has no way of knowing plot owners who have paid land taxes from the Land Registry because the Land Register is not integrated with the Tax Register. This type of database when implemented would facilitate access of such information to the KRA as the PIN Numbers are integrated with the Land Registry Numbers in the Database

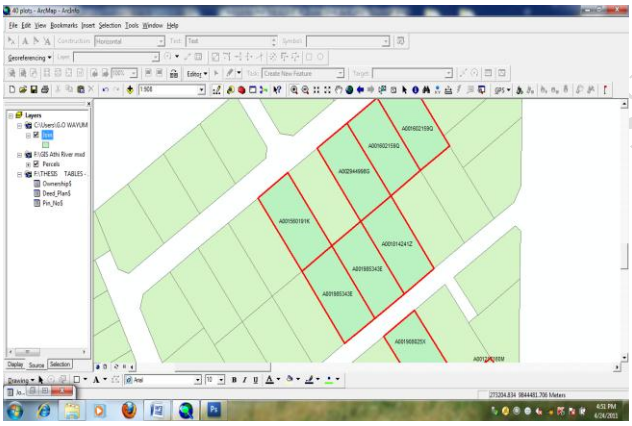

Table 1.11: Label Query to show PIN Numbers of plot owners (Source; Lab work)

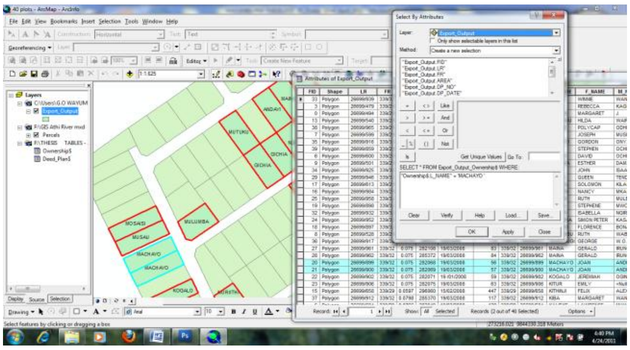

Table 1.12: Query showing multi plot ownership (1:M) Relationship (Source; Lab work)

Table 1.13: Multi-Owned plots labeled onto the cadastral digital map (Source: Lab work)

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