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Towards Adaption of Digital Geo-Info technologies in Urban Planning And Management: *The Case of Nairobi City, Kenya*

Dr. Andrew T. Imwati[1], Okoth George Odhiambo[2]

Abstract: ***Most planners and urban development managers in the region have met limited success as they sought to respond to the spatial development related challenges posed by the current dramatic urbanization syndrome trends, now taking place in most developing countries. Various reasons are given to explain the limitations that they normally encounter. These include inadequate geo-data and the inefficiency-prone traditional planning methods. Availability of reliable and comprehensive geo-spatial data is critical to effective spatial developmental planning and management at all level;, local, national and regional levels . This research paper therefore, attempts to examine the extent of mapping / planning geo-data needs and requirements in Kenya, and the potential of adoption and use of modern digital geo- information technologies (GITs) as alternative tools for geo- data provision, mapping, planning as opposed to hitherto traditionally used cadastral-based systems and approaches. The digital geo-information technologies under investigation are mainly; Remote Sensing (RS), Global Positioning Systems (GPS) and Geographic Information Systems (GIS).***

Keywords: Land use / Land tenure**;** Informal settlements; Land use management**;** Land use planning**;** Urbanization**;** Geo-Information Technologies (GITs)**;RS; GPS; GIS;** Geo-Data/Information**;** Spatial Planning/Mapping; Cadastral; Conventional systems

1. Introduction

1.1. Introductory Background

In the last few decades, the world has witnessed unprecedented demographic and spatial urban growth. This phenomenal urbanization trend presents urban planners and managers with enormous challenges in spatial development planning and management. This is particularly so in third world countries such as Kenya. The need for adequate mitigation measures for sustainable urban development management crisis now facing most developing and transitional countries cannot be overemphasized.

Availability of reliable and comprehensive geo-data/information is critical for meaningful spatial planning and development management. Unfortunately, however the traditionally used geo-data sources and acquisition systems, and the conventionally used planning approaches, are progressively getting limited in addressing the challenges posed by the dramatic urbanization trends currently taking place in most third world countries like Kenya.

Fortunately now, the rapidly advancing digital geo-information technologies (GITS), are currently gaining popularity as alternative sources of comprehensive, up-to - date and reliable sources of geo-spatial data in almost all fields. These modern geo-systems now offer unprecedented opportunities to planners, surveyors, land economists, and other professionals concerned with land based resource management, never than before. They include: Remote Sensing (RS), Global Positioning Systems (GPS), Geographic Information Systems (GIS), and the Internet based Geodata communication systems.

This paper therefore attempts, to briefly outline the potential of the above digital systems (GITs), against the hitherto used conventional, mostly cadastral-based geo-information systems, and spatial planning approaches as alternative tools for efficient spatial urban planning in addressing the current urban development crisis in Kenya in general, and Nairobi County in particular.

1.2. Current Urban Spatial Development Scenario in Kenya

Like many other developing countries, Kenya lacks effective spatial geo-information and planning frameworks for efficient urban development planning and management. This inadequacy has been largely attributed to the dramatic unprecedented and uncontrolled growth of small urban centres, rural markets, and expansion of medium and large towns and cities, such as Nairobi, without any comprehensive guiding structural development planning frameworks.

The above scenario can be blamed for the phenomenal and undesirable *epidemic-like problematic developments* of informal settlements, and unplanned temporary structures, now mushrooming in almost all urban areas in Kenya. Needless to say , the need for urgent policy, institutional and technical arrangements towards addressing the urbanization crisis, especially by the new county governments, cannot be overemphasized. Figure 1.1. conceptually attempts to illustrate the current spatial urban development scenario, its effects and implications and the need for urgent interventions and mitigation measures.

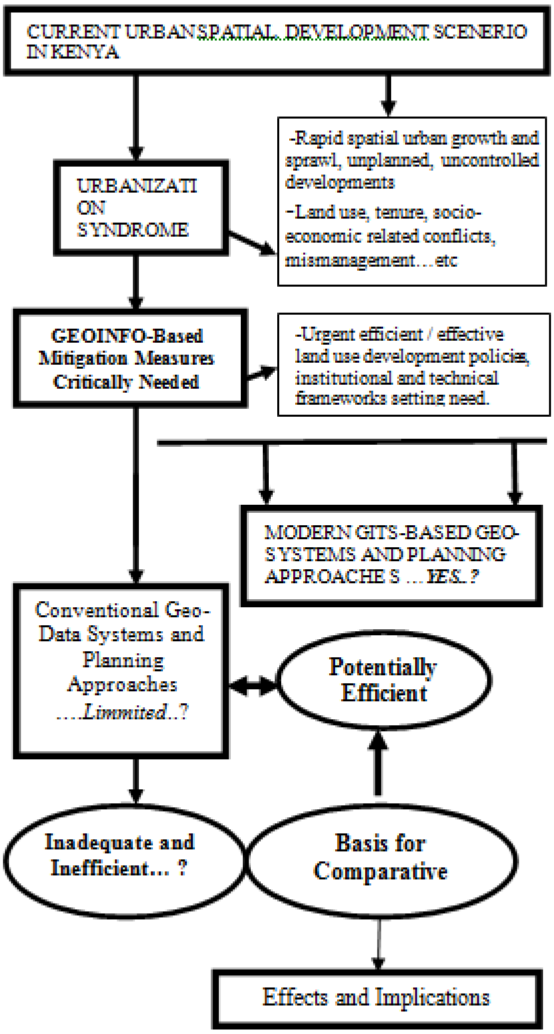


Figure 1.1: Current Urban Development Scenario and Needs in Kenya

1.3 Study Area Definition and Location

As large and medium cities and towns, such as the City Nairobi, continue to indiscriminately encroach into adjacent rural fringes, the new settlements are now targets for unprecedented dynamic spatial developments in most developing countries, albeit without coordinated development guidelines and/or control. Peri-urban settlements are currently "zones of conflicts" in that they are characterized by incompatible and conflicting spatial developments, jurisdictional administrative systems, socio-economic, and conflicting cultural and political systems. The emergence of this dynamic interface zone with its complex problems of adjustments between rural and urban systems has led to a myriad of socio-economic, spatial environmental, management and administrative challenges that most local authorities now find it difficult to cope with [1]

Before Kenya's Independence in 1963, Nairobi City occupied only about 90 km^2 in spatial extent. After 1963, the 'Old City' boundaries were extended to cover the present City area of about 700 km^2. The new boundary limits enclosed the then agro-pastoral adjacent settlements now comprising of Langata, Waithaka, Riruta Parklands, Roysambu, Dandora, Ruaraka, Kahawa, Njiru, Embakasi (including Jomo Kenyatta Airport) and Mugumoini (Nairobi Game Park) as they are today (Fig.4.2). However the boundary changes were demarcated without any supporting and comprehensive long term strategic development plan to guide the spatial growth of the extended metropolis [2],[3].

Since the 1963 boundary changes, the gazetted City limits have remained much the same despite the city's astronomical demographic and spatial growth over the last few decades. As indicated in Table 4.6, the 1979, 1989 and 1999 National Census for example, estimated the population of Nairobi City at about 0.828, 1.325 and 2.137 millions respectively (Kenya Rep., 2005). Currently the population is estimated at over 3.5 million people (Kenya Rep., 2008). This reflects a growth trend of about 40 % every 10 years or 4 % per year. At this rate the functional City jurisdiction is estimated to host a population of about 6 million by the year 2030. This demographic growth has been accompanied by the City's economic influence and spatial expansion from its former jurisdiction limits of about 700 km^2 to now encompass about 15 local councils and municipalities of the neighbouring Districts of Kiambu, Thika, Machakos and Ol-Kajiado with an estimated functional metropolitan region area of about 32,000 km^2. This spatial growth has led to rapid mushrooming of the new residential-cum-commercial satellite centers and informal settlements that now skirt the old city jurisdiction and the neighbouring urban councils without any comprehensive and coordinating physical development plan, a situation that now present City Hall and the neighbouring local authorities with numerous planning and management challenges.

Study Area Location

Figure 1.2 is a map of Kenya showing the location of Nairobi City. Plate 1 is a 2002 Landsat satellite image of Nairobi showing other rapidly growing peri-urban settlements of the City. Note that Kibera, Mathare and Ngomongo slums are some of the major old informal settlements within the City boundary limits that urgently needs replanning for upgrading purposes.

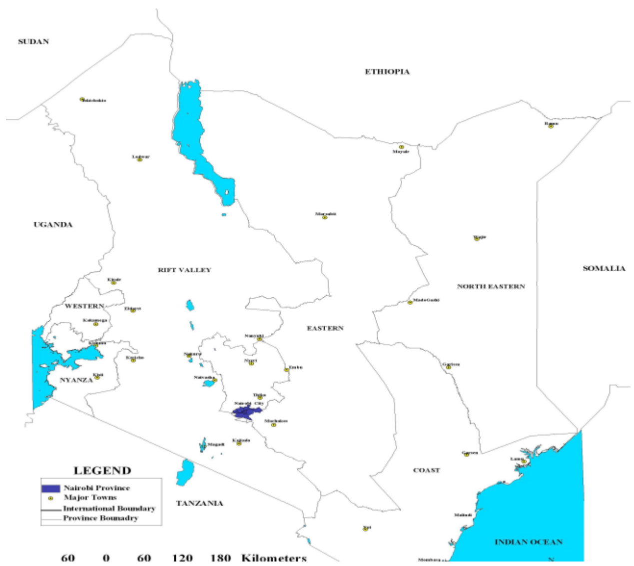


Figure 1.2: Map of Kenya Showing Location of Nairobi City

Source: Survey of Kenya, (2006)

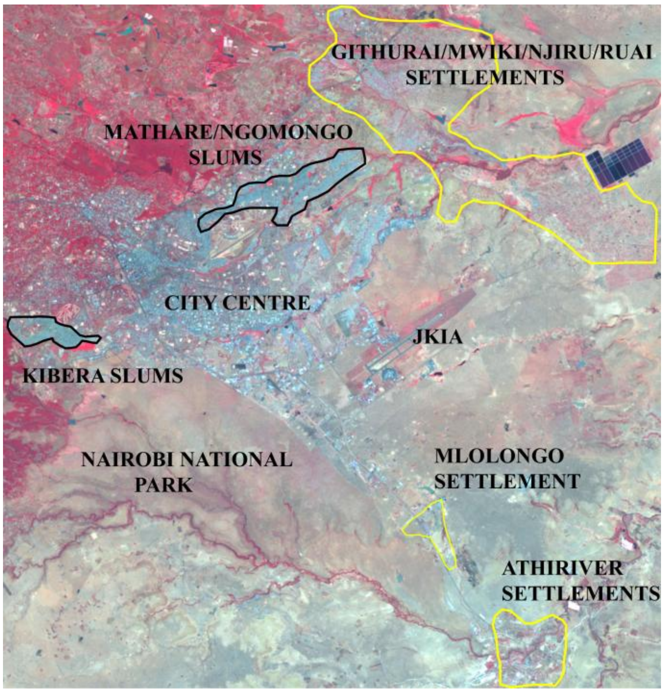


Plate 1: Some of old and new Peri-urban Settlements of Nairobi City

Source: Kenya Institute of Survey and Mapping, (2006)

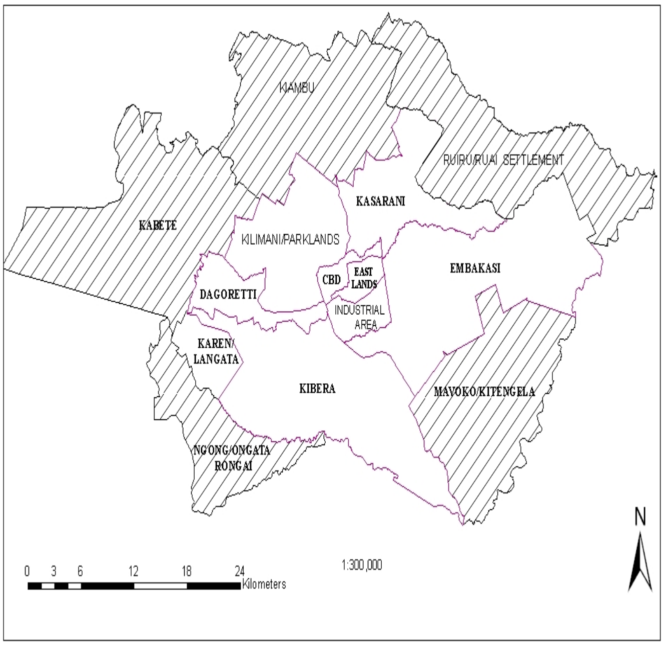


Figure 2.2: Rapidly **Growing Peri-Urban Settlements of Nairobi City**

Legend:

1. Rapidly Growing Peri-Urban Settlements of Nairobi City
2. Administrative Units within Official City Boundary Limits

Source: Derived from SOK Maps Catalogue (2006)

2. Theoretical and Conceptual Background

2.1. Planning Theory and Concepts

Concepts of planning have been variously defined and preferred by various writers [5],[6],[7],for example, defines planning as the process of allocating resources, particularly land in such a manner as to obtain maximum efficiency, whilst paying heed to the nature of the built environment and the welfare of the community. [8],[9] further defines planning as the art of anticipating change, and arbitrating between the economic, social, political and physical forces that determine the location, form, and effects of spatial development, both in urban and rural settings.

Spatial planning encompasses a variety of basic activities such as land use zoning, infrastructure services delivery, development control and environmental management, and other spatial and socio-economic development programs that are aimed at achieving envisioned and desired goals within the natural and built environments of a given land space.

2.2. Spatial Planning Geo-Data Needs and Requirements

Planning process requires various multi-contextual and multi-dimensional geo-spatial data sets, including; various land use types, land tenure, socio-economic, spatial environmental management, community health, shelter provision, communication, utility infrastructure and services provision etc. For effective planning purposes, the data should be availed comprehensively, reliably and in acceptable formats, accuracy standards and at the right scales, depending on the planning task at hand. For example large scale topo-cadastral maps of 1:1000 - 1: 10,000 are necessary for detail urban planning while medium scale base maps of between 1:10,000 – 1:50,000 are required for most general planning activities.

The source and comprehensiveness of geo-spatial data is of crucial importance to the effectiveness and efficiency of any given planning and management programme. In Kenya, for example planners have largely depended on slim geo-data resource base provided by the *restrictive conventional cadastral based mapping and geo-data acquisition systems*. Faced with the rapid urbanization trends, the demand for alternative sources of rapid and comprehensive geo-data is overwhelming.

Hence the need for harnessing alternative geo-spatial data sources that is now offer by the kindred digital geo-technologies, namely; Remote Sensing (RS), Geographic Information Systems (GIS) and Global Positioning Systems (GPS).

2.3. Conventional Geo-data Acquisition Techniques

Conventional *cadastral-based* geodata acquisition techniques have been, hitherto the basic source of spatial data needed for various land use planning in most countries, Kenya included. As earlier elucidated, however, the techniques are currently increasingly becoming limited in providing planning data as comprehensively, reliably and rapidly as demanded by the dynamic urban development trends in most third world countries.

Traditional cadastral surveying and mapping involves tedious, rigorous and costly ground measurements processes. The principle and concept behind the rigorous processes is to mathematically measure and represent each ground feature or point of interest on a map or plan as accurately as possible, in either two dimensions coordinates (x, y) or in three dimensional orthogonal (x, y, z) .

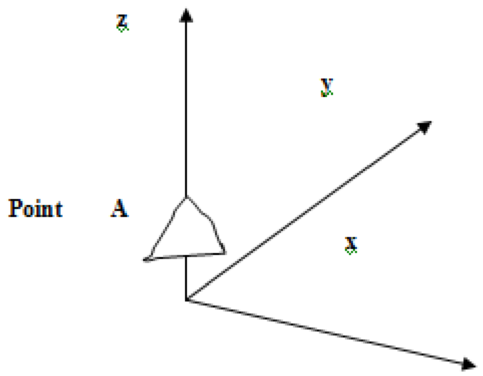


Figure 2.4: Orthogonal Plane (x, y, z) Coordinate Mapping System

It is from such vector measurements that various cadastral maps and plans are prepared and produced through complex mathematical computations and cartographic techniques. Figure 2.5 shows an example of a 2D cadastral map illustrating vector coordinate data. It requires high level of training in surveying and mapping techniques for one to successfully carry out such surveys.

2.4. Modern Geo-data Acquisition Techniques

The rapid development and advancement of modern digital geo-technologies, namely; Remote Sensing (RS), Global Positioning Systems (GPS), Geographic Information Systems (GIS), and the Internet Communication Technology (ICT) are now providing the much needed sources of current, uptodate, reliable, affordable, rapid and comprehensive, multi-contextual and multi-dimensional geo-spatial data that, if properly adapted, provides unprecedented potential for various land-based resources mapping, planning development and management activities [11]

2.4.1. Remote Sensing Technology (RS)

[12],[13] defines remote sensing technology as the science and art of obtaining information about an object, area and/or phenomena through the analysis and interpretation of data acquired by a device that is *not in contact* with the object, area or phenomena under investigation.

Remotely sensed (RS) data, mainly satellite imageries and aerial photos, provide wealth of spatial data that portray physical features/developments *in* reality as illustrated in Plate 3.1. Such data can be used directly (raw) or when geo-referenced/rectified (processed and accuracy improved) for various mapping, planning and management purposes. For example, RS now provide an important source for both *static* and *dynamic* geo-spatial data provision that can effectively be used to rapidly assess, monitor and/or study static, dynamic phenomena and other spatial developments *stereoscopically* in *three dimensions (3-D) representation.*

RS data has tremendously improved in accuracy over the last few years. For example commercial satellite systems such as QuickBird, IKONOS and SPOT are now providing image data at resolutions of between 0.5-1.0 meters which is sufficient for most detail urban planning and mapping at scales of between 1:1,000 and 1:10, 000**.** Such data can easily be ordered through the Internet within 1-2 weeks or purchased from local vendors, e.g. Regional Centre for Mapping of Resources for Development (RCMRD) at very affordable costs.

2.4.2. Global Positioning Systems (GPS)

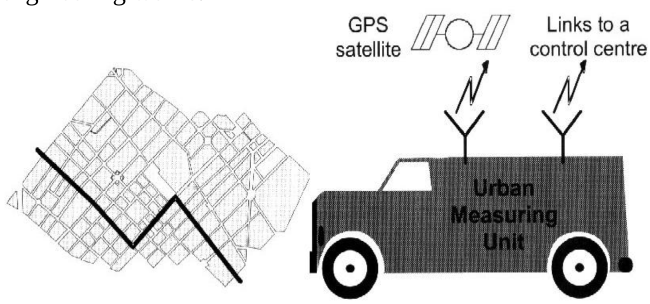
Global Positioning Systems (GPS) *has become a solution to one of man's longest and most troublesome problems. It now (instantaneously) provides the answer to hitherto bothersome question, 'Where on earth am I?' For many centuries, this problem was solved using the sun and the stars* [14]

Global Positioning Systems are rapidly gaining popularity as important tools for providing spatial position (coordinates) data rapidly for various mapping and planning activities. GPS now provides valuable technique for mapping built-up un-surveyed and/or un-planned areas such as informal settlements, which would have been difficult and costly using conventional ground mapping techniques.

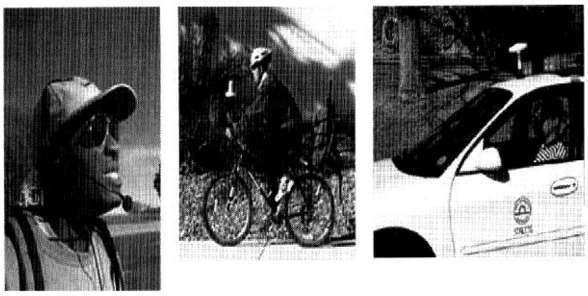
It today costs relatively affordable amount of money (about US$ 500) for a small-scale survey with improved accuracy of about 1- 2m. Hand-held GPS sets now provide majority of planners and surveyors with handy tools for rapid field data collection. Its capability for direct digital data input and merging with RS data in a GIS data base, further makes GPS invaluable tool for comprehensive digital mapping, plan drafting and production for various spatial development purposes.

Other GPS-based methods of acquiring data remotely using devices such as *lasers and range finders* are rapidly gaining popularity. These innovations are usually combined with GPS techniques to collect spatial data from aerial or terrestrial view points.

The use of voice technology that is continually being improved is another emerging technique for rapid data collection. For example, suppose somebody walking, biking or driving is equipped with a voice device that he can use to capture description of his environment and what he sees. By directly storing this voice information (verbal description), or transmitting it to the control office together with GPS coordinate positions (using even cell-phones), this spatial data can spontaneously be availed for field phenomena assessment, monitoring, and other spatial planning and development activities, such as traffic flows and progress of engineering works.



(a) Illustration of vehicle with sensors connected to GPS and the path of the vehicle making real-time measurements



(**b**) Examples of voice-based technology in spatial data collection; A Headset Microphone, Biking Unit and a Car Unit

Figure 2.7: Simple GPS-based Innovations for Field Data Acquisition

Source; After Laurini, (2001)

2.4.3.Geographic Information Systems (GIS)

A modern Geographic Information System (GIS) may be defined as a computer-based system that is designed to gather, manage, analyze, display and disseminate geo-coded and geo-referenced data and information [15]

A modern GIS differs from other computer based drafting systems such as AutoCAD in that GIS offer additional capabilities of performing spatial analysis that other systems lack. It is also differs from traditional land information systems (LISs) in terms of scope and data content as can be seen from Table 2.3. It is to be noted that LISs were initially designed to support parcel-based cadastral operations and other small scale land use management functions before the modern GIS gained in popularity and complexity. A typical desk-top (PC-based) GIS is composed of software, hardware, data and temporal components as illustrated in Fig.2.7 a & b.

3. Planning Process and Geodata Needs in Kenya

3.1 Spatial Planning and Mapping Process in Kenya

Spatial planning and mapping processes in Kenya are mainly governed by the two Acts of Parliament, namely the Physical Planning Act Cap.286[17]and the Survey Act, Cap 299 [19] The inherent weaknesses of the two Acts and other related land statutes have, to a large extent, played a big role to spatial planning and management inefficiencies in the country’s urban settlements[20]For instance, the rigid procedural requirements prescribed by the two statutes are generally lengthy, complex and bureaucratic in nature, hence significantly contributing to the inefficiencies of development planning and management process. Inadequacies in geo-spatial data, especially in respect to base mapping that is vital for spatial physical development plan preparation, can be attributed to the slow and expensive cadastral-based surveying and mapping process that is used in the country.

The planning approach is also generally based on the Master Plan Model of planning that was adopted from Britain by-laws and regulations at independence in 1963, more than four decades ago. The master plan approach basically rely on rigid regulations and centralized town planning system that effectively capture the dynamic urban sprawl from central areas of urban centres into the peripheral areas. This has lead to the emergence of a dual development pattern for most urban centres, a planned central area and generally unplanned peri-urban zone. The unplanned peri-urban zone is in most cases found in the adjacent private freehold land which is haphazardly subdivided and developed with or without proper planning guidelines. These settlements are now characterized by informal settlements, land use and tenure conflicts and lack basic infrastructure services and facilities.

Conventional cadastral based geo-data acquisition systems have variously been blamed for contributing to inadequate data for planning. [21] for example, observed that, though the government has endeavored to regularize informal settlements in the country, it has been faced with daunting administrative constraints mainly due to continued use of strict requirements of cadastral mapping techniques that were designed in the 1950's and are now, not only antiquated, but also ineffective for rapid and comprehensive mapping of complex spatial developments found in informal settlement areas.

While investigating customary tenancies in the urban and peri-urban areas of Mombasa District in Kenya,[22] also observed that most of the informal land tenure/use rights were recorded in the *clan's collective memory* due to lack of reliable geo-information system. He noted that verbal data *(mental registers)*, customarily transmitted from generation to generation, were unreliable in terms of spatial and legal accuracy, hence the need for proper planning, mapping and documentation system if the land use management crisis and related conflicts in the district are to be effectively mitigated.

3.2 Planning GeoData Needs and Requirements in Kenya

The Department of Surveys, Ministry of Lands Survey, is the main provider of various types spatial data for planning activities in the country. The data supplied by the Survey of Kenya (SOK) mainly include various types of cadastral maps/plans, topographic, geodetic and trigonometric data, aerial photographs, special and thematic maps and other land related statistical data, which are in most cases obsolete and outdated for all purposes. Other spatial data such as land adjudication maps, local development plans and statistical records are found in various provincial and district land department offices. Unfortunately this data resources base is not only inadequate, but mostly out-of-date and of limited planning use where it exist.

Table3.1: Topo-Maps; Most with Contours at Varying Vertical Intervals

Series	*Scale*	*Coverage*	*Availability*	*Planning uses*
Y731	1:50,000	Coast, South, Central and Western Kenya	Limited Old editions	Limited use due to age
SK61	1:50,000	Most urban and other potential areas	Ltd. old and new editions.	Very useful for urban and regional planning activities
Y633	1:100,000	Northern and	Available	Regional planning

		N. Eastern Kenya		not much used
Y503	1:250,000	Whole of Kenya	Available	National administrative boundary planning
	1:1,000,000	Whole of Kenya	Available	Limited regional and national planning uses
SK80	1:2,500,000	Kenya, Tanzania and Uganda	Limited	Limited national planning uses

Source: SOK (2012)

Table 3.2: Township Maps and Plans

Series	*Scales*	*Description and Coverage*	*Availability*	*Planning Uses*
SK13	1:2,500	Topo-Cadastral for old Nairobi City Centre	Limited – not in Production	Very useful for detail urban planning if production resumed
SK59	1:5,000	Annotated Photographic Mosaic for old Nairobi City	Limited – not in Production	Very useful for detail urban planning if production resumed
SK88	1:10,000	Topo-cadastral for some parts of Nairobi City	Limited; production slowed down or halted	Very useful for detail urban planning if production resumed

Source: SOK (2012)

The existing spatial data and other land records in the custody of the Ministry of Land Departments, and various municipality and local authority land offices are grossly inadequate in meeting the current spatial planning and management demands. Most of the geo-data is archaic, unreliable, scattered, and inadequate and unmanaged where it exists, and hence cannot effectively serve any meaningful land use planning and management purposes.

For example, investigations at City Hall revealed that various departments dealing with spatial and socio-economic planning, development and management issues are in dire need for up-date and reliable geo-data/information.

Given the level of the current planning data inadequacies, financial and technical capacity constraints, the country heavily relies on external donor support for most of its large-scale mapping projects. In 2003 for example, a Japan International Cooperation Agency (JICA) sponsored aerial mapping project for Nairobi City was undertaken and completed in November 2005. The project was aimed at establishing a comprehensive spatial data framework for the City. The mapping provided topographic maps at 1:2500 scales for the City Center and 1:5000 for the rest of the municipality. Unfortunately, the adjacent peri-urban settlements were not covered in the mapping . A similar project (by JICA) was underway for the port City of Mombasa.

Photogrammetric mapping projects of such magnitude and scale runs into hundreds of millions of shillings, a cost that is beyond the reach of local municipalities in the country without external support. There is need, therefore, for cheaper alternatives for mapping the rapidly growing urban and peri-urban areas if the spatial development crisis in the country is to be effectively mitigated. Projects such as the Habitat that sponsored Kenya Slum Upgrading Programme (KENSUP) are difficult to implement in absence of adequate mapping of these settlements.

Faced with the scarcity of the necessary a few local authorities such as Nakuru Municipality have also initiated mapping projects using modern technologies. In the year 2002, for example the Municipality initiated a project named, Local Urban Observatory (LUO) database system aimed at supporting spatial planning and management of the rapidly growing township**.** The system includes development of a modern GIS and the use of remote sensing (RS) and GPS data acquisition techniques. Other municipalities such as Mombasa, Kisumu City and Machakos have expressed their desire for initiating similar projects, although they face financial, technical and manpower constraints.

4. Conventional Vs GITS Based Planning / Mapping Models

4.1 Cadastral-Based Mapping / Planning Model Used in Kenya

As earlier mentioned, planning and mapping processes in Kenya are strictly governed by both the Planning and Survey Acts. The two statutes generally involve lengthy and complex official procedures and technical requirements. For instance, survey and development plans for a given subdivision scheme and/or proposed development project are subjected to various stages of scrutiny before approval and implementation. In reality the process is even more intricate than what is indicated.

4.2 Proposed Modern GITs-Based Mapping / Planning Model

Conceptually, modern GITs-based technology offers alternative viable mapping/ planning approaches as compared to conventional processes. Basically, the process entails the use of remotely sensed data (high resolution geo-referenced satellite imagery and/or aerial photographs), GPS and GIS for rapid and comprehensive geo-data acquisition, drafting and map/plan preparation and production. As compared to the largely manual and tedious conventional cadastral-based techniques, GIS digital techniques facilitates faster automated data processing, analyzing, correlation, merging, maps and plans compilation, preparation and production, geo-data/info storage, access and dissemination.

5. Conclusions and Recommendations

The following conclusions can therefore be drawn from the investigation:

1. That the need for urgent effective and efficient government land policy, institutional and technical paradigms for land-use development planning, and management cannot be overemphasized, if the challenges posed by the current *urbanization syndrome* (rapid growth) in Kenya are to be effectively mitigated.

2. That spatial planning /mapping geo-data dearth is critical in Kenya, especially for the rapidly growing urban and peri-urban settlements in the country, hence the need for official adaption of alternative forms of data sources now being offered by the emerging geo-info systems, as opposed to the use of cadastral-based geo-data acquisition systems that are solely recommended by the Director of Surveys for mapping and planning purposes in the country
3. That though modern digital geo-data acquisition (GITs) are of relatively lower accuracy levels, their advantages as alternative mapping and planning tools far out-weigh those of conventional geo-systems in terms of cost-effectiveness and affordability (in terms of money and time costs), availability, currency, comprehensiveness, user friendliness, flexibility, computerization and automation.

For example it has been demonstrated above that GITs-based mapping/planning process may be approximately 10 times cheaper than conventional cadastral-based process in terms of monitory and time costs. It was also found that GITs can afford measurement accuracies of about 1 in 1500 (or about +/- 0.5m), which is good enough for most urban mapping and planning purposes, especially at common scales of 1: 2500, or better if carefully used. This therefore offers unprecedented opportunities to planners, surveyors and other land professionals concerned with land use development planning and management matters, especially in rapid development milieu.

Note: The paper is based on actual real case research study carried out by the author for his PhD Degree Programme in 2010, at the University of Nairobi, Kenya.

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Author Profile

Dr. Andrew T. Imwati is Lecturer in Jomo Kenyatta University of Agriculture and Technology; Geomatics Engineering and Geographic Information Systems Department

Okoth George Odhiambo is a GIS specialist and Researcher from Jomo Kenyatta University of Agriculture and Technology; Geomatics Engineering and Geographic Information Systems Department