Journal of Environmental Management and Safety (JEMS)

Journal homepage: www.cepajournal.com

Urban Growth Management of Nigerian Cities: A GIS Approach

Okosun A. E
Department of Urban and Regional Planning University of Nigeria, Enugu Campus
Ndukwu R. I and Chiemelu N. E
raphik2006@yahoo.com
nduchiemelu@yahoo.com
emmanuel.chiemelu@unn.edu.ng
Department of Geoinformatics and Surveying University of Nigeria, Enugu campus

ARTICLE INFORMATION
Article history
Received 11 November 2009
Accepted 12 December 2010

ABSTRACT

The problems of rapid population growth and physical development of Nigeria cities have been a source of concern for urban planners and policy makers in recent years. The rate of population growth is observed to be astronomically high, particularly in the urban canters. As a consequence, the sizes of cities in Nigeria are growing in a haphazard and uncontrolled manner. Over the years, successive governments in Nigeria have taken bold steps to tackle physical development problems in the country. For instance, Physical planning was enacted and town planning authorities were established to guide the development and growth of the cities in the country. Despite these efforts, haphazard developments still persist in Nigerian cities, thus resulting in myriad of problems such as congestion, slum growth, urban cramp, sprawl development and degraded urban environment. These observed failures are attributable to ineffective and out-dated existing development control tools such as zoning, subdivision and building codes. The paper is aimed at redressing these problems in order to ensure an orderly, physical urban development and good city image in Nigeria. GIS is one such, new and effective technique to achieve this

purpose. GIS provides excellent analytical tool for ensuring effective development control and management of Nigerian and indeed other African cities.

Keywords: Geographic Information System, Urban Growth, Management, Urban Areas.

1.0 Introduction

In the last decades, poor urban growth management has continues to attract the attention of researchers and stakeholders in urban planning. This may be attributed to the inevitability of urban growth in most cities in the upcoming decades (Sadik, 1999). The magnitude and potential scale of the anticipated growth will precipitate tremendous impacts in the form of population explosion and mounting pressures on the carrying capacity of the environment. Due to the projected growth pattern, over five billion people will be residing in urban areas by2025 with 80 percent of that number in developing countries. Such a trend poses a difficult task for urban planners and natural resource managers in containing the problem (Masser, 2001).

The extent and nature of other challenges confronting urban planners are enormous and these include: inadequate infrastructure, meager resources for service delivery and planning, conflicting interests between groups, and the contradicting priorities embedded in economic development (Devas et al., 1993).The inability to effectively manage these related challenges is rapidly increasing human risks associated with poor housing conditions, waste generation, over-consumption of limited freshwater supplies, untreated waste water and urban air pollution. Accordingly, this has prompted a growing interest on the application of Geographic Information Systems (GIS) as a viable tool for urban growth management. The paper attempts to explain the use/application of geospatial information system (GIS) in urban growth management in Nigeria. The idea is to ensure efficient functioning of the urban centers in our quest for road map for sustainable urban development in Nigeria

2.0 Issues of Urban Growth Management in Nigeria

The idea of Urban and Regional planning in Nigeria originated in Britain during industrial revolution in the 18th century. Chadwick (1971) states that planning is a process of human forethought and action based upon that forethought and it is aiming at the best use of land and greatest possible

'improvement in the human environment'. Planning human living environment is obviously easier said than done. The physical, socio-economic and environmental aspects are particularly of major concerns and should be taken into consideration in the planning process. In recent times, however, most cities in Nigeria are expanding in an unplanned manner. CUEM observers that:

> *Today, our cities are growing rapidly and expanding in all directions to the extent that some like Lagos, Kano, Port Harcourt, and Warri …are now threatened to become huge, difficult to manage mega cities, sprawling multi-centred settlements covering enormous physical areas*. (CUEM, 1997, p.167). .

The catalysts of rapid expansion of Nigerian cities are natural increase and rural-urban drift. The course of becoming a developed country has posed a lot of difficulties and challenges to Nigeria. This situation has created numerous problems of urban growth management such as imbalance in land use allocation, overcrowding, pollution and loss of natural resources (Gana 1996; Okeke 2000; Eduputa 1998; Njungbwen 2008).

Apparently, urban problems in Nigeria are almost insurmountable with respect to the vicious spiral urban squalor, unplanned growth, congestion and poverty, which in turn are fuelled by rural-urban migration and resource depletion. Thus, planning and managing the urban areas has become a difficult task in dealing with issues and problems associated with urban development and growth. Besides, the loss of urban greenery, increase in water and air pollution, erosion, flooding, haze, and unpleasant odour occur due to improper physical planning. Therefore, effective urban planning and management practice is imperative in order to forestall further unplanned urban growth in the country.

To this end, successive governments in Nigeria have taken bold steps to redress the challenges posed by uncontrolled urban growth. Some of the measures are the formulation of the National Urban Development Policy of 1992, promulgation of the Urban and Regional Planning Law of 1992 and the establishment of the Federal Ministry of Environment in 2004.

In spite of these efforts, Nigerian cities are still undergoing unprecedented changes in population and spatial extent. The explosive growth of Nigerian urban centers has exacerbated interrelated problems of human settlements and the environment (SHSDN, 2004). One of the principal reasons adduced for this worrisome situation is the obsolescence and weakness of the existing planning tools for providing a sustainable basis for urban development in Nigeria.

For effective and functional urban growth management, data are required on changes taking place within and around the cities. Such data are vital to urban development and prevention of uncontrolled expansion and its consequences. For instance, land use changes require continuous updating of lands and their analysis so as to determine the rates and direction of city growth. These analysis and spatial information cannot be extracted from the out-dated hand drawn maps because most of the information contained there in are not necessary (Adeboyejo and Abolade, 2006).

3.0 Geographic Information System (GIS)

Geographic Information System (GIS) is an emerging information tool that can perform active role in urban development management. GIS can be defined as a computerized system that permits or facilitates the phases of data entry, data analysis and data presentation especially in cases when dealing with geo–referenced data (Rafed, 2000). GIS has the capabilities of data based management, mapping, image processing and query and statistical analysis. A GIS defines features or entity or real world objects on a map using spatial and descriptive or attribute data. Spatial data indicates information about location and dimension of a feature.

The advent of (GIS) has created a large field of opportunity for development of new approaches to computer processing of geographically referenced data, which add a new dimension to the management, analysis and presentation of large volumes of information required in decision-making process. The use of GIS has enhanced the rationality of the decision making process by improving data and accessibility and as a consequence leads to better decision. One important GIS capability is in handling both digital cartographic data and the associated databases of attribute information for map features (Healey, 1988). GIS systems can store the map coordinates of point locations, linear and areal features. These features have attributes that must be stored in the database. Once all the data are stored, both the digital map and the database can be manipulated simultaneously. This is particularly important in many land use planning applications, which require data on a wide variety of physical and environmental attributes.

GIS Sub Systems and Components

GIS consists of sub systems and components.

GIS Subsystem

Basically, GIS is divided into three subsystems namely:- data acquisition, database management, and information presentation subsystem.

(a) Data Acquisition Subsystem: They include all hardware, software, and other components meant for the acquisition of data. Examples are GPS, Total Station, Analytical and Digitizer, Echo Sounder, etc. The software includes micro station, survey computation software, SKI for GPS and Hydrographic Software.

(b) Data Management Subsystem: It includes hardware, software, spatial database, procedures and expertise used for the storage, manipulation, analysis, and retrieval of spatial data. The hardware include: personal computers, mainframe, workstations, desktop, notebook, while the software include: dBase, Oracle, Ingress, Access.etc

(c) Information Presentation Subsystem: This includes hardware, software and procedures for result presentation. The hardware includes computer, plotter, and printer. While the software is made up of Aldus Freehand, Adobe Illustrator, Map Publisher, Microsoft word, Netscape,etc

Components of GIS

The system is made up of five major components namely:

- Hardware components
- Software component
- Spatial database: this is always referred to as the heart of GIS since it contains data
- Procedure: these are algorithms and rules used for integrity implemented as convention and operation in the database
- Expertise: these are people who provide the technical know how in the operation of the use the system.

However, it is important to note that all the five components of are always present in each subsystem.

4.0 Geographical Information System (GIS) and Spatial Planning

In planning analysis, information is derived from printed maps, field surveys, aerial photographs and satellite images. GIS enables data from wide variety of sources and data formats to be integrated together in a common scheme of geographical referencing, thus providing up-to-date information (Grimshaw, 1988; Coulson and Bromley, 1990). GIS has long been accepted as the most appropriate solution to address spatially referenced data. The essence of GIS in the plan making process can not be over-stressed. According to Calkins (1972), better planning will be achieved through better information, and better information will necessarily flow from an information system.

The evolution of computer and information technology has had a significant impact on the planning profession in the last few decades. Ayeni (1997), and Briassoulis (1999) explains that the approach emphasizes (1) the need for as much scientific and technical information as possible to analyse comprehensive planning problems; (2) the use of scientific analysis and mathematical models to design optimal solutions; and (3) the primacy of technical and technological solutions to these problems. These strongly support the requirements of computer-aided techniques in the planning process.

Fundamentally, a GIS is able to support all the stages of spatial data processing including manual or semi-automated digitizing, checking and editing of digitized data, edge-matching of digital map files and output of information to graphic devices or hard copy plotter.

The major functions required from an information system can be identified as follows:

(i) The descriptive function - information should help to describe the situation;
(ii) The cognitive function – information system also contribute to improve understanding of urban and regional problems by providing the key factors and variables that can be analyzed, using urban and regional models and other statistical techniques;
(iii) The normative function – the information system can also contribute to improved action by reducing the cost of actions with known consequences or by reducing uncertainty about the consequences of action already taken or about to be taken.

In an era of increasing urban and regional problems, the planning authorities therefore must increase their effectiveness by developing innovative ideas in carrying out their functions. The urban system can no longer be treated in terms of simple land use and traffic concepts. The planner's conception of the urban system must extend to include a host of social, political and economic variables. The mixture of problems which must all be resolved together creates a situation in which many alternatives must be tried, combined, improved and tested by analysis, by experiment, and by public discussion. The information system therefore must expand correspondingly if anything like effective understanding and control must be achieved. An information system is part of the mechanism for reducing uncertainty in the knowledge and understanding of the environment. The development of GIS provides a tool which can contribute to much clearer understanding of real planning problems as well as prescriptive planning

scenarios to enhance the quality of urban planning and management (Yaakup, 1991).

A GIS provides the facilities to deal with data requirement for the functions described above. An important GIS capability is in handing both digital cartographic data and the associated databases of attribute information for map features (Healey, 1998).GIS can store map coordinates of point locations linear and area features. These features have attributes that must be stored in the database. Once all the data are stored, both the digital map and database can be manipulated simultaneously. This is particularly important in many land use planning application, which requires data on a wide variety of physical and environmental attributes. Another main driving mechanism of any GIS is the ability to inter-relate data sets. Since the relative positions of different map features are known to the system, sophisticated analysis of relationship between features across geographic space can be performed. The primary focus in the manipulation stage is the overlay and neighborhood analysis.

A GIS is able to support all the stages of spatial data processing including manual or semi automatic digitizing, checking and editing of digitized data, edge matching of map files and output of information to graphic devices. In physical planning, for example, urban growth and management information is required from variety of sources such as printed maps, field survey, and aerial photographs and satellite images. GIS enables data from wide variety of sources to be integrated together in a common scheme of geographical referencing, thus providing up-to-date information (Grimshaw, 1998).In addition, GIS has the capability to hand Temporal (time base), aspatial information and as well measure spatial interaction-vital for planning activities.

4.1 GIS and Urban Growth Management

Growth management refers to how urban designers and policy makers deal with change in spatial structure of a city. The intent is to provide greater predictability about where, when, and how much development will occur in a county, community, region or entire state (Daniels, 1999; Porter, 1997). More so, growth management seeks to balance the benefits of growth with the costs imposed on the environment and the quality of life (Perin, 1977). Several approaches to growth management have been identified in the literature. Pro growth refers to the use of development to turn a fringe community into a suburb. Balanced growth seeks to target some areas for growth and environmental protection. No growth or slow growth entail making development difficult and keeping change to a minimum (Daniels, 1999). From this policy standpoint, growth management legislations require various

levels of governments to identify lands with high natural resource, economic and environmental value and protect them from development. Some growth management laws require that public services such as water and sewer lines, roads and schools be in place before new development is approved, while others direct governments to make decisions in accordance with comprehensive plans that are consistent with plans for adjoining areas.

Most growth management programs are established at the state level and may apply to the entire state, high-growth counties or a particular region. Growth management laws can protect farmland by channeling new development away from important agricultural areas (Washington, 2003). Notwithstanding these objectives of growth management and the role of policy instruments of command and control in actualizing them, the lack of a GIS approach can some times scuttle the implementation of well-intentioned programs into opposite directions. Therein lies the growing need for GIS applications in growth management over the years.

4.2 Existing Tools for Urban growth management

These are:

- Master Plan
- Building Control
- traffic and transportation planning
- Infrastructure development /management

4.3 GIS Approach to Urban growth management

GIS technology has long been applied in planning activities including the master plan, building control, traffic and transportation planning and Infrastructure development.

Master Plan: A Master Plan lays down the basic framework for guiding and regulating future growth. This is done through 3 basic instruments:

1. Land use Zoning Plan that determines the use of each land parcel in the development area
2. Structural Road Network Plan that guides laying of the trunk infrastructure in the development area
3. Development Control Regulations that determines the built form in the development area

It is a statutory document and must be prepared by every city/development area. It therefore must be based on recent and accurate information about the city/urban area.
The plan preparation process is severely constrained by lack of availability of basic information starting with accurate maps, data pertaining to the land uses, road networks, structures, open spaces, water bodies etc. Worse still, existing obsolete city maps (master plan) are common especial in developing countries like Nigerian. Further more, most of the secondary information is spread across diverse departments/sources, not updated, and the process of procuring is cumbersome. Unfortunately there is no systematic way of collecting, maintaining and analyzing data/information that may be relevant for planning purposes.
In this era of information technology, the most crucial information for preparing a Plan is an accurate and updated Base Map of the planning area, road networks, spatial extent of development and the information on the use of each parcel of land. It is the basis for making rational planning decisions. Use of Satellite Images and GIS can fill this gap by providing the following information products:

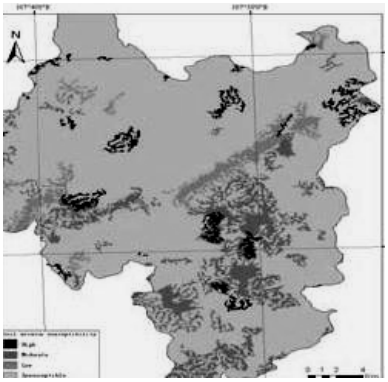
- Base Map
- Land Use Map
- Urban Sprawl, rural settlement and their expansion
- Direction of development/identification of the growth corridors
- Detailed land use maps with plot wise and floor space ratio

- Buildings heights showing the intensity of development
- Open spaces – with a detailed database, which helps in estimating the open space deficiency and the appropriateness of spatial location.
- Social infrastructure – schools (public, private), hospitals (public, private), community facilities, etc.
- Urban Heritage structures – Shrine, important monument and buildings

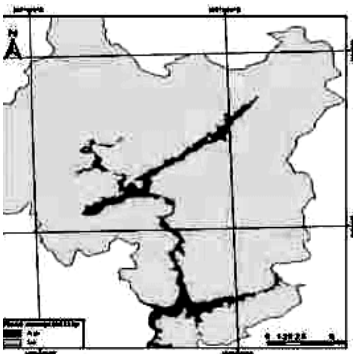
Building control: Building control is one of the main tools for the implementation of master plans. In building control, master plan and other local plans provide the planning guideline for new development. If these plans are prepared in proper GIS compatible format, proper identification of site and relevant planning parameters and building by- laws can be done within a very short time.

Identification of Environmental Sensitive Areas

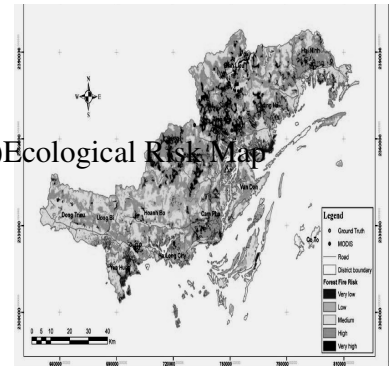
The generation of environmental sensitive areas and high-risk zones maps are very helpful in planning and decision making process as the identified sensitive areas can be avoided from being developed. If the area must be developed, high-risk zone maps can act as guidelines to further justify the type of development that is to be implemented. GIS can assist by providing for this purpose (see Figure 1).



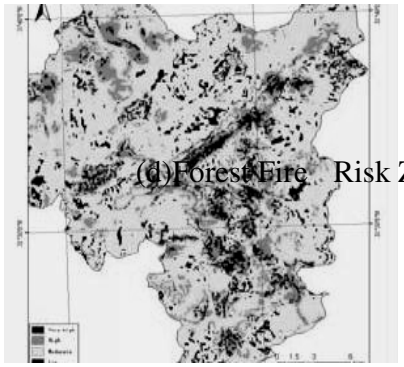
(a)Soil Erosion Susceptibility Map



(b)Flood Susceptibility Map



(c)Ecological Risk Map



(d)Forest Fire Risk Zone Map

(c) Forest Fire Risk Zone

(d) Ecological Risk Map

Figure 1: A Composite of High-Risk Zones Maps
Source: Adapted from Minxia, Z. et al (2008)

Urban Renewal: Urban renewal is a useful method for upgrading deteriorating urban neighborhoods. Stress analysis technique can be applied using spatial analysis capability of GIS for identification of high and medium stress areas that require immediate attention. For instance, identification of dilapidating buildings and slum areas, using satellite images in a GIS environment is an important part of the whole procedure .GIS, in addition to its analytic capability can provide the necessary data component required for stress analysis.

Urban sprawl: Patterns of sprawl and analyses of spatial and temporal changes could be done cost effectively and efficiently with the help of spatial and temporal technologies such as Geographic Information System (GIS) and Remote Sensing (RS) along with collateral data.

The spatial patterns of urban sprawl over different time periods, can be systematically mapped, monitored and accurately assessed from satellite data (remotely sensed data) along with conventional ground data (Lata et al., 2001). Mapping urban sprawl provides a "picture" of where this type of growth is occurring, helps to identify the environmental and natural resources threatened by such sprawls, and to suggest the likely future directions and patterns of sprawling growth. Integration of GIS and remote sensing means a complex integration of remote sensing data processing, GIS analyses, database manipulation and models into a single analyses system (Michael and Gabriela, 1996). Such an integrated analysis, monitoring and forecasting system based on GIS and database management system technologies requires an understanding of the problem and the application of available technologies. The integration of GIS and remote sensing with the aid of models and additional database management systems (DBMS) is the technically most advanced and applicable approach today.

Encroachment: Identification of encroachment traditionally is carried out by field visitation and physical measurement. With a GIS, encroachments can be identified by simply overlay the present plan and original layout plan.

Management and provision of facilities: Planning authorities are responsible for providing facilities and services for urban dwellers. To provide these facilities, deprived areas of these facilities must be determined. The traditional methods for this task are based on circular radius/diameter where distance is the only possible criterion. With GIS both serviced areas and deprived area of facilities can be easily determined, using network analysis. In network analysis, the actual road network and other criteria such as distance, time, etc are used for analysis.

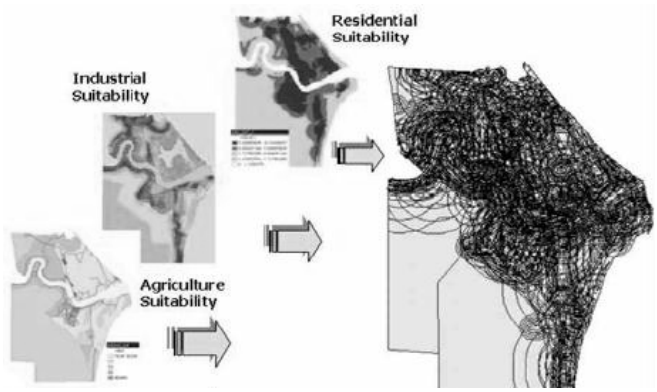
GIS analytical models and planning decision support system

GIS can be integrated as a component of a Planning Support Systems (PSS), which can support decision-making and urban problem-solving to a considerable extent. In this context, GIS will serve first, as a display and communicative device for producing maps and charts that describe past and present conditions. Secondly, it provides model outputs that suggest alternative features, which support decision making. Integration of GIS in PSS means combination of GIS data, urban model and presentation technique using computer for planning purposes. A combination of sophisticated GIS macro commands and traditional programming language can be used to develop analytical models closely linked to full-featured GIS toolkits (Klosterman, 2001).

Application of GIS in Development Plans System

GIS technology can be applied in planning activities, which essentially include plans formulation as well as development control (Johar *et al.*, 2003). Preparation of development plans at national, state and local government levels in the country requires a comprehensive information system in order to determine the trend and pattern of developments within a specific time frame as well as identify strategic land use and conservation policies. At various levels of plan preparation, GIS can be used mainly for data compilation, land suitability analysis and generation suitability maps (Yaakup, 2001). Figure 2 shows results of a land suitability analysis. For example, it is possible to generate from a GIS map products containing thematic layers of population and job distribution at the national, state or local council levels. The map can be analysed to identify the relationship between population and job created. Such analysis becomes important in projecting future requirement for housing, commercial floor space, school, recreational facilities, etc. In terms accessibility and transportation, GIS network models for trip generation, travel pattern, gravity model and travel mode can be useful in inter-region or intra-region connectivity.

Figure 2: A Composite of Land Suitability Maps



Source: Adapted from Yaakup, A et al (2005)

Smart Growth Challenges

GIS can address the challenges of proffering an acceptable solution for smart growth of cities. For example, with a visual GIS-based model, older suburbs can be assisted in assessing their redevelopment plans and the implications of their land-use development on quality of life within the communities.

5.0 Conclusion

The paper has attempted to discuss how GIS can be used as a veritable tool for urban growth management. The ability of GIS to integrate data from different sources, such as remote sensing, topographic maps, land use maps, cadastral maps, facility maps, etc., with their related attribute data for various analysis, has been seen as of great advantage in managing and monitoring our environment on typical issues such as urban growth management. For instance, the fact that GIS has effective analytical capabilities, which enable spatial information to be acquired, stored, processed, manipulated and queried for various results and applications has placed it at an advantaged position as a relevant tool for planning and decision making especially in the area of environmental management. Geographic database being the hub of a GIS can be extensively used to generate several alternative solutions to urban growth problems. Recognizing the importance of up-to-date base maps for effective planning, there is need to utilize the opportunities facilitated by modern geo-spatial technology through the integration of satellite images with GIS for the production of such maps with high accuracy for the cities of this country. For this reason, planners and Urban designers in Nigeria are therefore encouraged to embrace GIS technology and harness its potentials in our search for

sustainable urban development which is one of the strategy for realising Millennium Development Goals.

References

Adeboyejo, E. A. & Abolade, O. (2006) "Analysis of Spatial Changes in Ogbomosho City", *Journal of the Nigerian Institute of Town Planners*, Vol. xix No. 1 pp. 35- 48.

Ayeni. B. (1997) "The Design of Spatial Decision Support Systems in Urban and Regional Planning", in Timmermans. H. (ed.) *Decision Support Systems in Urban Planning, London*: E & FN Spon

Briassoulis, H. (1999). "Who Plans Whose Sustainability? Alternative Roles For Planners", *Journal of Environmental Planning & Management.* 42:6, pp.889- 893.

Centre for Urban Environmental Management (1997) *Handbook,* Netherlands, p.167

Chadwick, G. (1971) *A System View of Planning.* Pergamon, Oxford, p.63.

Coulson, M. and Bromley, R. (1990). "The Assessment of the Users Needs for Corporate GIS: The Example of Swansea Council", *Proceedings of the European Conference on Geographic Information Systems,* Amsterdam, EGIS Foundation, Utrecht, pp. 209-217.

Daniels T. L., 1999, *When City and Country Collide: Managing Growth in the Metropolitan Fringe.* Washington, D.C: Island Press.

Devas N,, Rakodi C, (1993), "The Urban Challenge", in Devas N.,C. Rakodi, (Eds). *Managing Fast Growing Cities: New Approaches to Urban Planning and Management in the Developing World.* New York: Longman, Essex, U.K., and John Wiley & Sons

Eduputa, B. M. (1998) "The Role of Professionals in the Management of Nigerian, Urban Environment", A Paper Presented at the 29th Annual Conference of the NITP Makurdi, Benue State, October, pp. 1-13.

ESRI, 1995, *Using the Arc view GIS: The Geographic Information System for Everyone.* Redlands, California: Environmental Systems Research Institute Inc.

Federal Ministry of Housing and Urban Development (2004) Sustainable Human Settlements Development in Nigeria, Abuja

Gana, I. K. (1996) "A Comparative Study of Development Control Implementation in Minna and Bida, Niger State", unpublished PhD Thesis, Department of Geography, University of Ilorin.

Goodchild, M. F., (1989) "Modelling Error in Objects and Fields", in *Accuracy of Spatial Databases*, edited by M. F. Goodchild and S. Gopal (London: Taylor & Francis), pp.107-114

Harris, B. and Batty, M. (1993). "Location Model, Geographical Information Systems and Planning Support System", *Journal of Planning Education and Research, 112:1, pp. 43-62.*

Klosterman, R.E. (2001) "Planning Support Systems: A New Perspective on Computer Aided Planning", in Brail, R.K. and Klosterman, R.E. (eds) *Planning Support System*, ESRI Press, Redland, California

Lata K. M., Krishna Prasad V., Badrinath K. V. S., Raghavaswamy, (2001). "Measuring Urban Sprawl: a Case Study of Hyderabad", *GISdevelopment*, Vol.5, p.12.

Masser I., (2001) "Managing our Urban Future: The Role of Remote Sensing and Geographic |Information Systems", *Habitat International,* 25:503-512.

Michael, F. B., and Gabriela, M. A., (1996). "Remote Sensing and Geographic Information Systems", *Hydrological Sciences, Journal des Sciences Hydrologiques*, Vol. 41(4): pp 593 – 607

Njungwan, E. et al (2008) "Historic Land Use Changes in Uyo Urban Area and Implications for Urban Environmental Management", Paper Presented at the 2-Day National Conference, Organized by the Department of Urban and Regional Planning, University of Nigeria, Enugu Campus, 12^{th} – 14^{th} September.

Okeke, D. C. (2000) "Urban Land-Use Planning and Informal Sector Syndromes: A Case Study of Enugu", *Journal of Nigerian Institute of Town Planners,* Vol. xiii, NO. 1 pp. 50 – 65

Perin C, 1977, *Everything In its Place.* Princeton, NJ: Princeton University Press

Porter D.R., (1997) *Managing Growth In America's Communities.* Washington, DC: Island Press

Sadik. N. (1999), "Meeting the Urban Population Challenge", *City Development Strategies,* 1:16-23

Yaakup, A.B., Johar, F. and Dahlan, N.A. (1997). "GIS and Decision Support System for Local Authorities in Malaysia", in H. Timmermans, *Decision Support Systems in Urban Planning*, E & F SPON, London