ANALYSIS OF THE PATTERN AND URBAN MANAGEMENT IMPLICATIONS OF SPRAWL IN KADUNA METROPOLIS - NIGERIA

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DECLARATION

I declare that the work in the thesis entitled 'Analysis of the pattern and urban management implications of sprawl in Kaduna Metropolis, Nigeria' has been performed by me in the Department of Urban and Regional Planning under the supervision of Dr A. Ahmed and Mr. U. Momoh.

The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at any university.

…….. …… ……

Name of Student Signature Date

CERTIFICATION

This thesis entitled 'ANALYSIS OF THE PATTERN AND URBAN MANAGEMENT IMPLICATIONS OF SPRAWL IN KADUNA METROPOLIS, NIGERIA' by Aliyu, Yakubu Bununu meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

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ABSTRACT

The accurate mapping and analysis of urban sprawl has been a major challenge to urban planners. This has links to the shortcomings of known procedures and techniques of analysis involving the use of manual methods, the Shannon's entropy and the GIS and Remote Sensing techniques. Consequently, the debate has existed on the need to develop viable tools to confront these challenges. This thesis demonstrates the application of a unified frame of sprawl analysis based on the integration of GIS, remote sensing and the Shannon's entropy as the improvement over the known tools. The major advantage of the tool is that it permits the concurrent time series mapping and analysis of the magnitude of sprawl as well as the simulation of sprawl implications. The argument being that establishing the pattern and urban management implications of sprawl on multiple spatial and temporal scales is needed to permit better management of urban areas. The approach also provides urban planners and managers with an accurate, precise, flexible and cost effective means of assessing sprawl.

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CHAPTER ONE

INTRODUCTION AND BACKGROUND TO THE STUDY

1.0 Introduction

This chapter introduces the research and places it in context. The subject of urban evolution and urban sprawl are first introduced and the research question is then outlined. The aim and objectives of the research are then presented and the chapter ends with an outline of the scope and delimitation of the study.

1.1 Background to the Study

Urban systems around the world are evolving in surprising ways. For the first time in history (2007), the urban population of the world has outnumbered the rural population (Badiane A. 2006). This epochal transition occurred mostly in Africa and other developing countries of Latin America and Asia. In fact, the world has urbanized faster than originally predicted by Malthus. In 1950, there were 86 cities in the world with a population of more than one million. Today, there are over 400, and by 2015, there will be at least over 550 (Badiane A. 2006). Cities have absorbed nearly two-third of the global population growth since 1950 and are currently growing by a million newborn and migrant populations every week. Forecasts show that the majority of the world's population will in the nearest future live in the urban areas of Africa and other developing countries in Asia and Latin America (Badiane, 2006). These kinds of transformations have given rise to a variety of urban forms as can be seen in the compact, somewhat densely built early European cities, dual city structures found in post colonial Africa, edge cities and sprawled cities with their

variant forms. As such, there has been an ongoing debate among scholars, academics and urban professionals as to what is the most desirable urban form. This debate has further been widened by the popularity of the sustainable development paradigm or the green agenda to the extent that the question being asked in the circle of academics, policy makers and urban professionals is: what is the most sustainable urban form?

Sprawl is a relatively new form of urbanization falling somewhere between Ebenezer Howard's ideas for Garden cities and Le Corbusier's notions of ubiquitous urban form (Kunstlar 1993 in Torrens 2006). Sprawl takes place either in radial direction around a well established city or linearly along highways. Patterns of sprawl and analyses of spatial and temporal changes could be done through various methods. The Mapping process 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. The socio-economic implications of sprawl are other concerns that are dependent on the mapping and study of the sprawl process. Ultimately, the power to manage sprawl resides with local municipal governments that vary considerably in terms of will and ability to address sprawl issues.

1.20 The Research Problem

Globally, population increase and rural-urban migration are the explanations for rapid urbanization. When the population of cities increases, expansion occurs either vertically or horizontally. The predominant tendency however is horizontal growth as a result of dispersal of development. This pattern of development creates sprawled

urban forms that usually come with implications on the city and its management. Sprawl is among the most important topics in urban studies. Factors explaining it have been widely studied, but the dynamics of its evolution and its implications on the management of cities is usually cumbersome to determine and quite often subjectively done. Effective assessment is dependent on tools that enable rapid appraisal over multiple spatial and temporal scales. By extension also, it should allow the simulation of urban sprawl implications that urban managers can readily use for management decisions.

The conventional tools for the mapping and analysis of urban sprawl are based on manual mapping methods that are slow, tedious, and expensive. The process is also dependent on qualitative descriptions which are widely criticized by researchers as being subjective. The Shannon's Entropy (SE) as an improvement over the manual methods is a statistical approach and has been used in quite a number of studies to quantify sprawl (Yeh et al, 2001; Lata et al, 2001 and Shekhar, 2006). Its shortcoming of giving measures of sprawl at a point in time rather than connecting resultant patterns of sprawl over different time epochs is what has led to the use of spatial and temporal technologies like the Geographic Information Systems (GIS) and Remote Sensing (RS). Though capable of providing mapping and spatial analytical functions, the GIS and RS also have shortcomings regarding computation analysis of sprawl indices.

The challenge of surmounting the shortcomings of known tools is with developing improved methods of analysis. In the context of this study, it shall come through the integration of the capabilities of GIS, Remote Sensing and Shannon's Entropy into one analytical frame (referred to in this study as the Integrated Sprawl Analysis Tool). The assumption being that by integration, a versatile tool can emerge to permit not only the mapping and statistical analysis of sprawl, but also the simulation of sprawl implications. The development of an interface that brings the three tools together is the contribution made in this study that requires demonstration. How viable is the integrated framework in sprawl analysis? And how useful is it in measuring sprawl implications? The study attempts to answer these two questions using Kaduna as a case study. Connecting the pattern and urban management implications of sprawl on multiple spatial and temporal scales is needed to permit better understanding and management of urban sprawl. It is envisaged that the integrated technique of sprawl analysis will provide urban planners and managers with an accurate, precise, flexible and cost effective means of undertaking a time-series analysis of urban sprawl and its resultant implications.

1.30 Aim and Objectives

1.3.1 Aim

The aim of this study is to examine the pattern and urban management implications of urban sprawl in Kaduna metropolis through the development and application of an "integrated tool of sprawl analysis" with the view to drawing of lessons for wider applications.

1.3.2 Objectives

The objectives of the study are to:

1. Review the concept of sprawl and the techniques of its analysis.
2. Develop a framework of sprawl analysis using the GIS, Remote Sensing and Shannon's Entropy techniques.
3. Examine the application of the technique in the spatio-temporal analysis of sprawl in Kaduna.
4. Simulate the urban management implications of sprawl in Kaduna using the technique.
5. Draw lessons and make appropriate recommendations.

1.4 Scope and Delimitation

The study is focused towards achieving the mapping and analysis of sprawl in Kaduna and the simulation and modeling of its implications on the management of the city through the integration of GIS, Remote Sensing and Shannon's Entropy techniques. The study is however limited to simulating the implications of sprawl at the aggregate town level utilizing the integrated sprawl analysis tool with complementary data like transportation and infrastructure costs introduced at the latter stages to simulate urban management implications.

1.50 Background of the Study Area

Kaduna was founded by Sir Frederick Lugard just after the turn of the century as an administrative and military headquarters for the Northern Territories of Nigeria. Located between Latitude 10^0 25' 31" N and 10^0 37' 38" and Longitude 7^0 01' 09" E and 7^0 29' 50" E, the capital was strategically placed almost in the centre of the region near the Kaduna River to serve as a stable source of water. The choice of its location in an area that is virtually uninhabited bush was to free it from any local political pressures that might be brought about by the many Emirs with their own entrenched and ancient seats of power in the existing towns. The first of Kaduna's plans were sketches made for Lugard with his wife's advice. The plans were heavily influenced by the precise labeling, rank conscious military mind with plots for senior and junior officers drawn up as on a parade ground below the Governor's house which is on the highest point. Commercial and trading establishments were allocated places well out of sight up in an area between the Sabon Gari and the European reservation albeit for health as well as on social grounds. The three north-South avenues were broad and straight. The main crossroads were narrower and slightly curved taking the harshness out of a basically grid-iron layout. Public offices, race course and a golf course were laid out in the centre. Barracks, parade grounds and depots (the raison d'être of the place) were put at a respectable distance away over by the railway. Trees were planted along the avenues, gardens encouraged as nostalgic imitations of the more comfortable English suburbs in the Surrey hills and finally a green (rainy season only) belt was fastened tight around. This then was the European reservation area, an immunized Island inhabited by servants of the crown-a little England with its social traditions and class distinctions. This area still exists, in fact considerably extended

from Lugard's original plan, but it is no longer exclusive in the way that once it had been becoming a desirable neighbourhood attainable to all who want to live there and can earn enough to do so, although it is still largely dominated by housing for senior government employees" (Theis, 2002). The indigenous population then was originally segregated into two major groups, which were: strangers, or Africans who were alien to the province of the north and natives, largely indigenous Hausa and other northern tribes from the immediate surroundings of the region.

The first of these were established in a township away from the green-belt wrapped around the European Reservation Area down one of the three straight avenues called Ahmadu Bello way, then known as Prince Edward way towards the river. This area is known as the Sabon Gari or strangers quarters laid out in a grid iron monotonous pattern. This was home to the African who had come up north with the army and government from the west coast. This gradually evolved to become the central core of Kaduna, the place for trade, entertainment, education and social activity. In an area across the railway to the west of Sabon-Gari was established the original public works department labour camp, then known as Anguwar Lebura now Tudun Wada. The main roads of Tudun Wada were wide giving a sense of 'place', somewhere to gather, talk and barter. Here lived the African from the north.

Times of course have changed and there is now a far greater freedom of movement based more upon the individual's ability to pay rather than his social or ethnic background. But the present physical and legal structure of Kaduna, and to a certain extent its social structure is still under the influence of these closely rigid early policies. As Kaduna grew in importance, so other settlements at first mere native

hamlets around the edge of the town, began to grow. To the North there are Kawo, Unguwar Shanu, Kurmin Mashi, Unguwar Rimi and Unguwar Kanawa. These settlements hitherto dependent satellites have witnessed tremendous expansion and that coupled with the expansion of the main town resulted in their integration into the fabric of the city as its constituent districts. On the South side of the river were three communities outside of the government reservation for the survey departments and the railway. These include the compact and somewhat isolated village of Barnawa which has over the years changed from its rural beginnings and is expanding everyday with people dependant on the town and the villages of Makera and Kakuri alongside the railway adjacent to the textile Mills. These two villages have expanded at such a rate that they have now coalesced into one sprawling mass. This has today become the well known industrial suburbs of Kaduna. As the city continues to expand, a number of suburban communities have emerged and are growing in size and importance in the hierarchy of urban activities within Kaduna metropolis. These communities include Rigachikun, Barakallahu, Kawo and Kawo Extension and Sabon Gida, in the north and Rigasa, Television village, Sabon Tasha, Narayi, Gonin Gora, Anguwan Romi, Mararraban Rido, Kudenda, Tsaunin Kura, Anguwan Gimbiya, Anguwan Bulus, Anguwan Sunday and Nasarawa to the south. Today, Kaduna is the capital of present day Kaduna state comprising of Doka, Gabasawa, Tudun-Wada, Kawo and Makera districts with a combined population of 1,710,694 (NPC, 2008).

CHAPTER TWO

SPRAWL: CONCEPT, CONTEXT, CONSEQUENCES AND METHODS OF ANALYSIS

2.0 Introduction

The chapter presents a literature review aimed at facilitating the understanding of the concept of urban sprawl and the debate surrounding the topic within the academic literature. The chapter is divided into five sections. The first, second and third sections review the concept, definition, evolution and characteristics of urban sprawl with a view to facilitating a broader understanding of the research subject. The fourth section focuses on the debate around sustainable development and the consequences of sprawl as well as the known methods for its analysis. The fifth and final section of the chapter dwells on the known strategies for the containment of sprawl in the planning literature.

2.1 Definition of Urban Sprawl

The practice of urban planning has a long history, most probably dating from the earliest cities many thousands of years ago. However, the modern concept of urban planning only really began to evolve in Britain during the second half of the nineteenth century as a reaction against the industrialization which had created such great inequalities in living conditions by exploiting for profit whatever did not have to be paid for directly, such as housing, air, water and workers health (Relph, 1987: 49). Urban planning evolved throughout the twentieth century, leading to a great variety of urban forms which often had little regard for their impact upon the environment. In both developed and developing societies, this disregard is most evident in the rise of

urban sprawl as the primary form of urban development, one which has come under increased criticism in recent years because of its negative environmental, social and economic effects (Newman and Kenworthy, 1989; Hillman, 1996; de Roo and Miller, 2000; Jenks et. al., 1996; Breheny, 1992; Elkin et. al., 1991).

The various definitions of urban sprawl in the planning literature have been summarized to create a working definition of the concept as: 'unplanned, uncontrolled, and uncoordinated single use development that does not provide for a functional mix of uses and is not functionally related to surrounding land uses and which variously appears as low-density, ribbon or strip, scattered, leapfrog, or isolated development. This low-density, single-use, automobile dependent type of development has come to dominate the urban environment in the past fifty years, and was brought about by a combination of regulatory, economic, social and cultural factors (Arbury, 2005).

However, urban sprawl is now viewed in a far more negative light in the planning literature, frequently implicated as causing excessive land consumption due to under-valuation of open space, congestion due to increased commuting, and socioeconomic segregation due to exclusionary housing markets (Carruthers and Ulfarsson, 2002: 315). Furthermore, sprawl development is now perceived as contributing to significant fiscal costs for infrastructure providers such as local governments (Burchell and Mukherji, 2003), and public health problems (Sturm and Cohen, 2004; Kelly-Schwartz et. al., 2004; Nozzi, 2003).

2.2 The Evolution of Urban Sprawl

Before the Industrial Revolution of the late eighteenth and nineteenth centuries, people mainly lived in rural areas or small villages. Even though cities had existed for thousands of years, and had been planned to some extent right throughout this period, only a tiny fraction of the world's population lived in urban areas (Elkin et. al., 1991). However, technological changes from the late 1700s onwards not only encouraged greater numbers of people to live in urban areas as factory work replaced many former farm jobs, some of which later became mechanized, but also fundamentally altered the structure of the urban environment through a series of technological innovations such as trains and electric trams.

Newman (1992) has identified three distinct time periods shaping the development of urban areas, and how the periods are closely linked with the available technology of the time. Traditionally cities had been characterized by a small, dense environment, often walled and generally not being much more than five kilometers from one end to the other. This form developed because of the need for all destinations to be within a reasonable walking distance, and can easily be seen in the design of most European cities, as well as the central parts of many older cities in Europe, Africa, North America, Australia and New Zealand.

The technological development of passenger trains and trams in the latter part of the nineteenth century enabled cities to form a new style of development, characterized by an increasing push outwards. Trains generated sub-centers, with the train station at

the heart of a number of pedestrian pockets with similar characteristics to that of the walking city; whilst trams created linear, grid-based development which followed the tram routes (Newman 1992). Cities could now spread up to twenty or thirty kilometers outwards depending on the technologies available, while where the rail lines met in the Central Business District (CBD) there was very dense activity. This technological development coincided with massive urbanization throughout much of Europe, North America and Australasia; as a result many of the cities in these areas have been strongly shaped by trains and trams, even if those transit systems are no longer in use today.

The third stage of urban development, based on the technological development of the automobile, began before the Second World War, but did not become the dominant form of development until after the war when the automobile progressively became the transport technology that shaped the city. Together with the bus it became possible to develop in any direction, first filling in between the train lines and then going out as far as fifty kilometers (Newman, 1992: 287). The automobile made low-density housing feasible, as people were no longer forced to live either near their place of employment or a transit station to transport them there. City functions could be separated through exclusive zoning patterns, enabling people to escape the pollution and bustle associated with industrial or business areas. The evolved form of many colonial and post-colonial African cities fit into these latter stages of urban evolution because contemporary urbanization in Africa started at a time coinciding with the period of the rising popularity and proliferation of the personal automobile.

Nevertheless, it would be naïve to state that the rise in automobile ownership alone has led to the rise of urban sprawl, as there are many other important contributing factors. Duany et. al (2000:7) believe that above all else, suburban sprawl is the direct result of a number of policies or their absence and failures in the case of the developing world that conspired powerfully to encourage urban dispersal. The most significant contributing policies in the US have been identified as the Federal Housing Administration and Veterans Administration loan programs, which following the Second World War provided mortgages for over eleven million new homes. Intentionally or not, policies such as these discouraged the renovation of existing housing stock, and placed great emphasis on the construction of single-family, detached houses, the foundation of low-density development (Duany et. al., 2000). Working in combination with rapidly rising rates of home and automobile ownership to further entrench low-density, automobile-oriented development was federal investment in a 41,000 mile interstate highway program, which coupled with federal and local subsidies for road improvement and the neglect of mass transit, helped to make automotive commuting affordable and convenient for the average citizen (Duany et. al., 2000: 8). In conjunction with these regulatory activities, which encouraged the decentralization of metropolitan areas, the emergence of 'zoning' over the past 80 years has contributed to the creation of single-use developments and the spatial separation of the home from almost all other activities which people are required to undertake on a daily basis. This is clearly another element of today's urban sprawl. In Nigeria, one can safely infer that it is in fact the absence of workable

urban development policies or the failures of existing ones that has resulted in the present sprawled form of most of our urban areas.

2.3 Characteristics of Sprawl

There are many characteristics that can be associated with the term urban sprawl although there remains debate in the planning literature with regards to the development of an exact definition for the term, and disagreement whether particular urban forms should be categorized as urban sprawl or not. According to Gillham (2002) there are four main characteristics of sprawl, which mirror the earlier definition given. These characteristics are leapfrog or scattered development, commercial strip development, low density, and large expanses of single-use development.

2.3.1 Leapfrog or Scattered Development

Leapfrog and scattered development go beyond the urban fringe to create built-up communities that are isolated from the city by areas of undeveloped land. In many ways these can be seen as the most extreme examples of urban sprawl, with a highly inefficient use of land, and a greater need to build highways and other infrastructure to service the outlying areas. Leapfrog development can be distinguished from 'satellite towns', a similar type of development beyond the urban fringe, by the former's much lower density and once again the almost exclusive reliance on the automobile as the method of transport for those living in such areas. The result is a haphazard patchwork, widely spread apart and seeming to consume far more land

than contiguous developments (Gillham, 2002: 4), and even though the open tracts of land are usually filled in eventually, leapfrog development remains an inefficient use of land.

2.3.2 Commercial Strip Development

Commercial strip development, another aspect of urban sprawl, is characterized by huge arterial roads lined with shopping centers, gas stations, fast food restaurants, drive-through banks, office complexes, parking lots and many large signs' (Gillham, 2002: 5). 'Strip development' is very low density and automobile dependent, with retail configured in long, low boxes (portakabins/containers) or in small pavilions which are always surrounded by large parking lots. Trips between the different retail outlets are almost always made by car, due to the 'spread out' nature of the strip, and there is little if any emphasis placed on the needs of pedestrians.

2.3.3 Low Density and Single Use Development

The third, and perhaps most commonly recognized aspect of urban sprawl, is its low density. Gillham (2002) describes the density of urban sprawl as lying between that of the crowded urban core and open countryside, but being much lower than older towns and cities. Buildings in 'sprawl' developments are generally single-story, widely spaced and with intervening parking lots and roadways. Density is normally measured in terms of population density, or dwelling units per area. The mixed-use, higher-density developments of early twentieth century cities, which facilitated both walking and the use of public transport, have been usurped by spatially dispersed cities and

'bedroom communities' of exclusive residential development, realistically accessible only by car.

2.3.4 Absence of Public Space

In addition to those elements of sprawl mentioned above, the absence of public space is a characteristic that truly identifies a 'sprawled' community from one that is not. As Gillham (2002: 7) elaborates, urban sprawl is distinguished by an unbroken fabric of privately owned land divided only by public roads. The major civic open spaces, parks and commons that grace many older urban-core areas can be few to nonexistent in much of the sprawled areas of today's cities. Clearly urban sprawl is a complex phenomenon, involving the four aspects listed above.

2.4 The Effects of Sprawl: Sustainability and Sprawl

The term *sustainable,* in reference to human development patterns, first appears to have been used in the 1972 study of global resource use: *The Limits to Growth* (Meadows et. al., 1972). The authors of this work believed that the catastrophic collapse of global systems would occur midway through the twenty-first century if current growth rates and resource consumption continued, and that the only alternative was 'to alter these growth trends and to establish a condition of ecological and economic stability that is sustainable far into the future' (Meadows et. al. 1972: 24). At the time, such thinking was quite radical as the 'environmental movement' had barely emerged. However, events around this time including the 1972 UN conference on the Human Environment and the 1973 oil crisis forced many academics

and policy makers to accept that current trends could not be maintained forever, and that drastic measures may be required to conserve natural resources for future generations (Arbury, 2005). During the late 1980s and early 1990s sustainability became increasingly widely accepted; primarily due to the 1987 WCED report *Our Common Future* and the 1992 Earth Summit in Rio de Janeiro (WCED, 1987). The most commonly used definition of sustainable development, the recommendation of both the WCED report and the Earth Summit, is 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (WCED, 1987: 43). This definition recognizes the importance of ensuring that the needs of the world's population at the moment should be met, with consideration for the needs of people in the future.

Therefore, the concept of sustainable development, which has formed the basis of environmental law in many countries around the world over the past fifteen years is strongly related to the ethical norms of welfare, distribution, and democracy while recognizing that nature's ability to absorb human-made encroachments and pollution is limited (Naess, 2001). Haughton and Hunter (1994) have identified three basic principles of sustainable development: the principle of inter-generational equity; the principle of social justice; and the principle of trans-frontier responsibility. Each of these principles is seen as equally important in achieving sustainable development, especially when attempting to apply the concept in a situation such as designing more sustainable cities. The principle of inter-generational equity, or futurity, is what most people concentrate on when talking about sustainable development: the need to

consider the effects on future generations' needs and aspirations when undertaking any human activity (Haughton and Hunter, 1994). However, equally important in the eyes of the Brundtland Commission was the principle of social justice, (also known as 'intra-generational equity'): that poverty needs to be tackled in present generations as it is a prime cause of environmental degradation. Sustainability, according to the generally accepted definition, means a more even distribution of resources, wider participation in environmental strategies and policies, and always taking into account basic needs and common aspirations. Finally, Haughton and Hunter (1994) refer to the principle of trans-frontier responsibility, as the need for people to take stewardship of the global environment at a global level, which is necessary because many of the environmental problems (such as global warming) transcend national borders. The principle also requires developed countries to refrain from the exploitation of resources in other areas, which can distort regional economies and ecosystems.

However, there are major potential problems for those attempting to implement sustainability throughout the world's cities, as the concept appears to conflict with urbanism at a fundamental level. Indeed, Elkin et. al. (1991: 6) states that cities have never been sustainable; rather 'the process of urbanism in antiquity has been frequently linked with desertification in the hinterland. Cities have always exploited the surplus food and materials produced in the hinterland, and thus interfered with previously more cyclical ecological systems.' This fundamental conflict between sustainability and urbanism becomes clear when one analyses the environmental impact of urban areas. Cities house a concentration of polluters, from industry to cars,

which contribute to the disruption of the earth's carbon cycle and could lead to global warming. Moreover, the vast food and energy use of the city creates what has been termed an enormous 'ecological footprint'; the amount of land needed to support the modern city (Naess, 2001).

Furthermore, not only are today's cities unsustainable, but they are becoming more unsustainable all the time, as there is no doubt that the pre-industrial dense European city would have consumed far less than cities today which are characterised by urban sprawl. Nevertheless, it is clear that while cities may never be able to actually achieve 'sustainability', they can become more 'sustainable'. Haughton and Hunter (1994) have calculated that on average each city of one million people consumes 625,000 tonnes of water, 2000 tonnes of food and 9500 tonnes of fuel, and generates 500,000 tonnes of waste water, 2000 tonnes of waste solids and 950 tonnes of air pollutants on a daily basis. While this level of resource consumption is clearly unsustainable, it remains very difficult to devise ways to reduce the levels of resource consumption while maintaining the relatively high standard of living that people enjoy in cities. Although cities in the developing world are growing at a much faster rate than those in developed countries, the amount of resources used in these countries pales in comparison to the unsustainable use of resources in every large developed-world city. This means that increasing the sustainability of the world's developed and developing cities must be a priority for policymakers, as there is both potential for great improvement and available resources to help implement necessary changes.

Furthermore, as intra-generational equity is a key element to Brundtland's definition of sustainability, it is important to analyse the wider impacts of urban sprawl on today's communities, as well as how these impacts are set to develop into the future. Environmentally, there are two main concerns related to urban sprawl: the rate at which it is consuming the landscape, and the air pollution that such a high level of automobile reliance is causing (Williams, 1999; Newman and Kenworthy, 1989; Guiliano and Narayan, 2003; Garcia and Riera, 2003; Anderson et. al., 1996; Kenworthy and Newman, 1990; Keyes, 1982; Owens, 1986). As already mentioned, the great irony of urban sprawl is its attractiveness at the individual level, in particular the spacious sections and large houses of recent developments, but its destructiveness communally. According to Burchell and Mukherji (2003), 742 out of the 3091 counties in the USA are affected by urban sprawl, and 13.1 million of the 23.5 million projected households for the period 2000 to 2025 will be constructed in areas characterised by sprawl. Therefore, at least in the USA, urban sprawl is a widespread problem affecting much of the urban development that has occurred in the past fifty years. This ubiquity means that any negative environmental impacts of sprawl are very significant, not just affecting a small proportion of the environment. It also means that the loss of land due to development is significant, with the American Farmland Trust believing that about 400,000 acres of prime farmland is being lost to sprawl each year in the USA alone (Gillham, 2002: 75). This also leads to the destruction of natural habitat for many species, which as a result have become endangered or are on the brink of becoming so. Sprawl consumes land with particular ferocity, due to its highly inefficient form. This generally includes a surprisingly high

percentage of land in sprawled urban areas being devoted to the needs of the automobile, with many American cities having close to half their land area occupied by either roads, highways, parking lots or other automotive-serving facilities (Duany et. al., 2000). This compares with about ten per cent of more compact cities being devoted to the automobile, which would lead to a far smaller loss of productive land (Duany et. al., 2000). Here one can begin to draw a parallel between American cities and Nigerian cities especially the capital, Abuja.

The link between sprawl and air pollution is also becoming increasingly significant, with a great amount of interest being focused on the issue of global warming, and measures to reduce levels of carbon emissions. Regulation has markedly improved air emissions from industrial areas in the past thirty years, leaving the greatest percentage of emissions these days coming from automobiles. Furthermore, although each individual car now emits far less than cars made before 1970, due to cleaner fuels and better tailpipe technologies, this improvement has been almost completely negated by the rapid increase in vehicle miles travelled (VMT) throughout the last 30 years. According to Southworth (in Arbury, J, 2005) 'between 1980 and 1999 aggregate US highway vehicle miles travelled is estimated to have increased by more than 76 per cent, an annual rate which far exceeds increases in population, jobs and disposable incomes. The environmental impacts of such a rapid increase in VMT are immense. 'The US Environmental Protection Agency indicated that in 1997, motor vehicles emitted over 50 million tons of carbon monoxide into the air, over seven million tons of nitrous oxides, over five million tons of volatile organic compounds, 320 tons of

sulphur dioxide, and almost 15 million tons of road dust into the nation's air' (Nozzi, 2003: 2). Nozzi (in Duany, et al, 2000) goes on to state that: 'in 1991, air pollution from motor vehicles resulted in 50 to 70 million respiratory-related restricted activity days, over 850 million headaches caused by carbon monoxide, 20,000 to 46,000 cases of chronic respiratory illnesses, 530 cases of cancer, and over 40,000 premature deaths.' Moreover, these costs are borne by the general public, in particular pedestrians and cyclists, rather than those doing the actual driving. Air pollution is also generally worst in the inner-city, because of the natural concentration of activity and therefore traffic, which once again is inconsistent with the source of the pollutants: most likely to be suburban commuters. Building more roads to reduce traffic congestion, which is commonly misconceived as polluting more than fast-moving traffic has no positive effect on pollution levels, with the most car-friendly cities in the USA such as Phoenix, Detroit, Denver and particularly Houston having toxic air emissions just as bad, if not worse, than most other cities (Duany et al, 2000).

Economically, urban sprawl has been shown to be highly inefficient, especially in the provision of services and infrastructure by local governments. However, once again there is a strong mismatch between the individual economic effects of sprawl, and those on society. Deal and Schunk (in Duany et al, 2000) summarise this conflict by stating that : 'current low density sprawl development patterns are preferred because they are relatively cheaper for the developer and individual purchaser at the expense of the broader community and society as a whole.' Water and sewer infrastructure costs are one particular aspect of urban sprawl which can prove to be prohibitively

expensive for local governments. Burchell and Mukherji (2003) state that under conventional (sprawl) development in the US between 2000 and 2025 there is a projected expenditure of about $190 billion in providing necessary water and sewerage infrastructure expansion to primarily single-family detached subdivisions. Although much of this investment would still need to occur under a more compact-type development, multifamily units require fewer laterals, fewer outdoor sprinklers and generally use less water than single family homes. Road infrastructure is another area where significant cost savings could be made by focusing development in a more compact manner. 'Under conventional development, the US is projected to spend more than $927 billion during the period 2000-2025 to provide necessary road infrastructure, amounting to an additional two million lane-miles of local roads (Burchell and Mukherji, 2003: 1537). While there would still need to be significant investment under a 'managed growth' policy, the difference over the time period could be around $110 billion, or an 11.8 per cent saving in local road costs. As well as basic infrastructure costs, sprawl is also economically inefficient with regards to the cost of local public services. As development does not usually pay for itself, and required services include schools, hospitals and other government services, there is a significant cost to the public sector for urban development. Costs are generally lower in denser areas close to urban centres as economies of scale and absorption of existing excess capacity can reduce the need for expensive new developments (Burchell and Mukherji, 2003; Auckland Regional Growth Forum, 1999).

While the societal effects of urban sprawl are very difficult to measure accurately, they are also perhaps the most damning evidence of its unsustainability. Reduced social equity, negative health impact, a loss of community, segregation, polarisation and an inability to adapt to changing lifestyles and family structures are just some of the ways in which urban sprawl is said to adversely affect social sustainability (Gillham, 2002; Hillman, 1996; Deal and Schunk, 2004; Kelly-Schwartz et. al., 2004; Sturm and Cohen, 2004; Song and Knaap, 2004; Le Goix, 2005; Calthorpe, 1993; Nozzi, 2003, Duany et. al., 2000). Social equity is negatively impacted in many ways by sprawl: limiting transport options of the poor due to the high costs of car ownership and poor public transport; increasing the likelihood of poor people living in less desirable neighbourhoods; increasing fear and anxiety generated by high traffic volumes; greater exposure to air pollution and resulting poor health; and losing a sense of community as most people travel beyond the local neighbourhood to conduct their daily activities (Hillman, 1996). In the most extreme form of urban sprawl, the 'gated community', there is complete social exclusion of 'undesirables' through the loss of public space, including streets. The exclusivity of gated communities creates a self-perpetuating segregationist pattern, with children who grow up in such communities being less likely to develop any sense of empathy with those living outside the gate, and perceiving them as '*others',* with suspicion and contempt (Duany et. al., 2000).

While social impacts such as a 'loss of community' or 'a sense of exclusion' can be critiqued as being very vague, the health impacts of the 'sprawled society' clearly reveal a significant social cost, in addition to the economic costs already mentioned.

The effect of automobiles, the overwhelmingly dominant mode of transportation when urban sprawl exists, on health and well-being, leads to some very sobering figures. As Nozzi (2003: 4) notes: 'The number of people who die on US highways every year is the equivalent of a fully loaded Boeing 747 aircraft crashing every three days, killing everyone aboard. In 2000, almost 6.5 million motor vehicle crashes killed 41,821 people and injured more than three million.' Due to these figures, motor vehicle accidents are the leading cause of death for people in the US of every age between four and 33. In Nigeria, even though there is no reliable data on the frequency and casualty figures arising from automobile accidents, estimated statistics show a high rate of accidents leading to injuries and fatalities on the Nation's highways especially within the urban environments. Furthermore, it is claimed that the physical structure of sprawl development, through its greater reliance on the automobile as the primary method of transportation, discourages walking and other physical activities, therefore increasing the possibility of many physical ailments such as hypertension, heart disease and type-two diabetes (Kelly-Schwartz et. al., 2004; Badland and Schofield, 2005).

As outlined above, the negative environmental, economic and social effects of urban sprawl are widespread, diverse and clearly at odds with the concept of sustainability. This is not particularly surprising, given Elkin et. al.'s (1991) assertion that urbanism fundamentally conflicts with sustainability. However, what is clear from the above analysis of the urban sprawl literature is that improvements can be made with regard to the sustainability of our cities. Jenks et. al.,

(1996: 4) expand on this, stating that 'with such a large proportion of the population, the concentration of environmental problems, and consumption of resources, cities clearly appear to be the most important location for action to help the goals of sustainable development'.

Therefore, achieving urban sustainability has been identified as a key part of any shift towards achieving sustainable development on a global scale. Due to this challenge, much of the planning literature throughout the 1990s has concentrated on the question of how to design the urban environment in a more sustainable way, and to look for alternatives to the ubiquitous sprawl that has dominated most urban development since the Second World War.

Firstly, there is the need to identify what urban outcomes can be said to contribute to sustainable development. In response to this need, Naess (2001: 506) has identified five elements of urban development and spatial planning deemed necessary for sustainable development to occur. They are:

1) A reduction of the energy use and emissions per capita in the city to a level compatible with the ecological and distributional criteria for sustainable development at the global level;

2) A minimising of the conversion of and encroachments on natural areas, ecosystems and soil resources for food production;

3) A minimising of the use of environmentally harmful construction materials;

4) A replacement of open-ended flows, where natural resources are transformed into waste, with closed loops relying to a greater extent on local resources; and

5) A sound environment for the city's inhabitants, without pollution and noise damaging to the inhabitants' health, and with sufficient green areas to give opportunities for the population to experience and become emotionally related to nature.

Clearly, a fundamental shift in the form and function of the city will be required to meet any of these criteria for sustainability. Urban sprawl clearly conflicts with most, if not all, of the elements of sustainable development listed above. The UN's Agenda 21 and Habitat Agenda both suggest that the objectives of urban sustainability should include: 'a compact urban form; the preservation of open space and sensitive ecosystems; reduced automobile use; reduced waste and pollution; the creation of liveable and community-oriented human environments; decent, affordable, and appropriately located housing; improved social equity and opportunities for the least advantaged; and the development of a restorative local economy' (cited in Wheeler, 2000: 134). The concept of sustainability itself has been widely critiqued on the notion that it is too popular hence impossible to disagree with and also difficult to define. Traditionally, many North Americans, Asians and even Africans have defined success in terms of a big house on a big lot. Such cultural attitudes about landscapes, privacy, and leisure may inhibit the willingness to adopt sustainable practices that require social responsibility, and that entail significant spatial and behavioural changes. A sustainable society operates differently from the one we know now.' For

sustainability to be successfully implemented in future urban developments, either these cultural attitudes will need to dramatically change (which appears unlikely in the near future), or developments will need to be carefully designed to be more environmentally, economically and socially sustainable, but at the same time appeal to consumers as attractive places to live. The compact city concept attempts to provide a more sustainable alternative style of urban development to sprawl.

2.5 Measuring and Analyzing Sprawl

2.5.1 The Methods of Analyzing Sprawl

2.5.12 The Descriptive Tools

Researchers have developed a number of approaches for measuring and analyzing urban sprawl. Some of these approaches include;

2.5.12.1 The Impervious Metric

This aims to measure sprawl by calculating the change in the amount of built surface per capita, compares impervious change estimates derived from satellite imagery to population change data derived from census information. This approach is anchored on the assumption that urban sprawl is fundamentally defined as a relationship between population and the built-up environment. Human development typically converts native vegetation to impervious surfaces. Growth intended to minimize sprawl would limit the amount of impervious surface created with the influx of new residents to any given region. A principal challenge to this method is the difficulty in

measuring impervious surfaces using Remote Sensing Techniques. The method is also limited because it is not suitable for pattern analysis.

2.5.12.2 The Neighborhood Metric

This is another method that works on the principle of the population density at which mass transit becomes economically viable bearing in mind that sprawled districts are severely automobile dependent because they are characterized by rigidly separated residential and commercial areas rather than by neighborhoods with amenities in walking distance. It uses a variation on population density change analysis to assess the change in transit-friendly development as defined in the literature on public transit viability. A major challenge of this approach added to its shortcoming in pattern analysis is the data requirement for dasymetric mapping of population distribution and the utilization of the convolution kernel to assess density distribution at a map pixel scale.

2.5.12.3 The Permit Metric

This works by way of evaluating the annual number of residential building permits for new construction. Specifically, it monitors the percentage of those occurring outside established urban growth boundaries as a way of gauging whether growth is leading to sprawl, or the infill of existing developed lands. It evaluates the trends in permitted building activities in and outside of areas designated for development. A key challenge of this approach is the non-availability of the data on building permits because even in the developed societies of the United States and Western Europe

where the data is available, it is on record that obtaining and analysing it is quite expensive. Like all the other techniques, this is also limited in the sense that it fails to take into account the spatial dynamics of sprawl as represented by resultant patterns.

2.5.13 The Statistical Tool: Shannon's Entropy

Geographers study entropy levels in different population distributions and settlement patterns and use entropy-maximizing models to find the most probable pattern of spatial distribution in a system which is subject to restrictions. In the analysis of sprawl, Entropy works on the principle that naturally occurring virgin land and landscapes are viewed as the normal and orderly state of things. Urbanization and human activity act to alter this naturally occurring state thereby creating disorder. A measure of this disorder is what the Shannon's Entropy represents. Shannon's entropy (Hn) can be used to measure the degree of spatial concentration and dispersion exhibited by a geographical variable (Theil, 1967: Thomas, 1981). This measure is based on the notion that landscape entropy or disorganisation increases with sprawl. Urban land uses are viewed as interrupting and fragmenting previously homogenous rural landscapes, thereby increasing landscape disorganisation. The dispersal of built-up areas from a city centre will lead to an increase in the entropy value. This gives a clear idea to recognise whether land development is towards a more dispersed or compact pattern.

The Shannon's Entropy of a variable is defined as:

$$Hn = \sum Pi\ (\log n) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where: ***Pi*** = proportion of the variable in the ith zone

n = Total number of zones under study

The value of entropy ranges from 0 to ***log n***. If the distribution is very compact then the entropy value would be closer to 0 and when the distribution is dispersed the value will be closer to ***log n***, large value of entropy indicates the occurrence of urban sprawl. Since entropy can be used to measure the distribution of a geographical phenomenon, the difference in entropy between two different periods of time can also be used to indicate the change in the degree of dispersal of land development or urban sprawl (Yeh etal, 2001). This is a more scientific and objective approach at quantifying sprawl.

2.5.14 GIS and Remote Sensing Technique

Remote sensing and GIS can be used separately or in combination for application in studies of urban sprawl. When used separately, both remote sensing and GIS techniques will enable to some extent sprawl pattern recognition, mapping of patterns and spatial analysis. In the case of a combined application, an efficient, even though more complex approach is the integration of remote sensing data processing, GIS analyses, database manipulation and modeling into a single analyses system (Micheal and Gabriela, 1996 in Sudhira etal 2001). Such an integrated analysis, monitoring and forecasting system based on GIS and database management system technologies

requires an understanding of the nature of the phenomenon of urban sprawl 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. Remote sensing and GIS applications are growing very rapidly with the availability of high resolution data from state of the art satellites (LANDSAT, IRS-1C, Spot and Quickbird) and the advancement in computer hardware and software. These two technologies are however limited when it comes to the computation of the magnitude of sprawl or sprawl indices.

2.6 The Need for Robust Analytical Tools: Interfacing GIS, Remote Sensing and Shannon's Entropy

GIS and Remote Sensing are both spatial and temporal technologies that complement one another. While Remote Sensing provides a reservoir of high quality digital data for GIS applications, it can be said that GIS compliments Remote Sensing by being probably the only means of putting to good use the huge volumes of data derived from it. Shannon's Entropy on the other hand is acclaimed by researchers as a viable technique for quantifying the magnitude of sprawl using some measurable index (Sudhira and Ramachandra, 2001). Objective attempts at quantifying sprawl almost always come back to the issue of computing "area" and "density" which are then fed into some formula to enable the computation of a quantitative index of sprawl. This involves mapping relatively large areas and being able to compute measures of area and density accurately and quickly. Furthermore, if sprawl is to be analyzed following

its nature as a dynamic phenomenon, then there is a need for data to be generated on a time-series basis. Standing alone, neither GIS, Remote Sensing nor Shannon's Entropy can fulfill all of the requirements mentioned above. However, the integration of the three can help overcome all the shortcomings mentioned and achieve the mapping and analyses of sprawl and its implications effectively and efficiently.

Urban Sprawl is a dynamic phenomenon. This dynamism therefore necessitates that any approach at studying it requires tools that are capable of providing insights into what the situation was in the past, establishing the present and simulating likely future trends. Secondly, any tools employed in the analysis of urban sprawl if they are to be effective must provide the capability to ensure timeliness, accuracy, precision and cost effectiveness in the collection and analysis of sprawl related data. Conventional mapping and data collection methods are slow, tedious and expensive, and therefore do not fit the description above. The current state of available technology is such that only the integration of Remote Sensing and GIS can ensure this supposed journey into the past through dated satellite imagery, a sojourn in the present through current satellite image scenes and a peep into the future with reasonable accuracy through scenario building and simulation using data collected on a time-series basis.

2.7 Strategies for the Containment of Sprawl

2.7.1 The Compact City

Much of the planning literature from 1990 onwards focuses on the compact city: a concept designed to implement sustainable development within the urban

environment and to counteract the perceived negative social, economic and environmental impacts of urban sprawl. There have been many attempts to define exactly what a compact city is, ‘ but in general it is taken to mean a relatively high-density, mixed-use city, based on an efficient public transport system and dimensions that encourage walking and cycling’ (Burton, 2000:1970). Through intensification of development within the city, many problems related to urban sprawl have the potential to be overcome, reversing the unsustainability of sprawl-type developments. Compact city policies have often been designed primarily to reduce the use of private cars and to minimize the loss of open countryside. However, proponents of the concept claim more than just environmental benefits can be gained from intensifying urban areas; in fact ‘higher density settlements are argued to be more socially sustainable because local facilities and services can be maintained, due to high population densities, and therefore accessibility to goods and services is more equitably distributed’ (Williams, 1999: 168).

Furthermore, high density urban living is seen as a prerequisite for vitality, vibrancy, cultural activities and social interaction (Williams, 1999: 168). The rejuvenation of local economies, particularly in downtown areas neglected by urban decentralisation and sprawl, can potentially also be achieved through intensification. Therefore, at least theoretically, it appeared that a solution to the sustainable city problem had indeed been discovered in planning literature by the mid 1990s, although with scepticism from some such as Breheny (1992, 1996) and Gordon and Richardson (1997). Contention over exactly what a compact city is, and how a great variety of

urban forms have been promoted as being 'compact' has proliferated throughout the literature concerned with urban sustainability over the past fifteen years. According to Thomas and Cousins (1996: 54), initial impressions of the compact city invoke an intense medieval city, whose limits are clearly visible, and where the hub of activity is confined within the city's walls. While it is highly unlikely that urban planners advocate rebuilding walled cities, it is a confinement of urban activity that appears to be most desired by the supporters of the compact city theory. Indeed, Lock's (1995: 173) definition of a compact city as 'the process of ensuring that we make the fullest use of land that is already urbanised, before taking green fields or Naess' (1993: 309) definition of encouraging development to where 'technical encroachments on nature have already taken place' typify the approach of the compact city advocate.

However, although there may be consensus that the compact city is clearly distinct from urban sprawl, there still remain many questions surrounding exactly *how compact* the compact city should be, and to what extent it extends beyond a simple population density increase in the urban environment. Scoffham and Vale (1996) argue that it is highly important to ask these questions about what the compact city is; whether buildings should be brought closer together; whether the number of people living in buildings should be increased; whether it is dwelling density or activity density that needs to be 'compacted'; and what role a mix of urban uses has in the compact city debate. According to Pratt and Larkham (1996: 279) 'One of the key problems with the compact city hypothesis is that it brings very diverse concepts together under a potentially misleading banner'. Generally three aspects of the

compact city are identified: a high-density city, a mixed-use city, and an intensified city (Burton, 2002). The first two aspects are related to the form of the compact city, while the third focuses on the process of making the city more compact. This third point is critical because there are few opportunities for a compact city to be created from scratch, which in any case would appear highly contradictory given the aims of urban compaction. Thus more compact cities can only be achieved through a process of making existing cities denser, of encouraging more people to live in urban areas and of building at higher densities (Williams et. al., 1996: 83).

Therefore, there is general agreement that the 'compact city model' is based around an increase in density from current levels. Given that a main goal of the compact city model is to reduce the impact of urban development upon the countryside, most future urban growth will need to occur within existing city boundaries (Williams, 1999). In an attempt to replicate the 'supposedly desirable' densely developed cores of old European cities, many different methods of intensification have been proposed, such as 'the development of previously undeveloped urban land; redevelopment at higher densities of existing buildings or previously developed sites; sub-division and conversions; as well as additions and extensions' (Williams, 1999: 168). However, the nature of this density increase, the role of 'mixed-use' development, and the wide variety of international interpretations of the compact city concept are still contentious issues in the urban development literature. Lock (1995) claims that there is no technical or professional agreement on how best to measure density and that few planners are comfortable in distinguishing between net and gross residential density

or overall town density. This disagreement makes it difficult to draw out the components of urban intensification and to identify what types of intensification should be encouraged, and what should be avoided. The nature of urban compaction has been deemed very important (Burton, 2002; Breheny, 1996) because certain types of development are generally thought of as being more desirable than others – high-rise apartment buildings are often associated with crime, overcrowding and the 'failure of tower-block living' (Williams, 1999; McLaren, 1992); while high-density that is not characterized by high-rise is often thought of as 'town-cramming' (Williams et. al., 1996).

Throughout the early and mid 1990s there was widespread faith in the compact city model's ability to provide urban sustainability. This approach was apparently 'so dominant that it seems inconceivable that anyone would oppose the current tide of opinion towards promoting greater sustainable development and the compact city in particular' (Smyth, 1996 cited in Guy and Marvin, 2000: 10). However, where compact city policies had been implemented, follow-up studies began to show that the predicted benefits were not happening as they should have been, and that the claimed benefits of urban compaction are at the very least romantic and dangerous, and do not reflect the hard reality of economic demands, environmental sustainability and social expectations' (Thomas and Cousins, 1996: 56).

Furthermore, there was found to be a significant difference between the romantic, vibrant, traditional city and the reality of traffic congestion, poor environmental

quality and 'town cramming'; in other words 'the city' was something which many people wished to escape from, through suburbanisation and rural living, rather than embrace (Williams, 1999). As a result of the increased uncertainty surrounding the compact city concept, a clear critique can be developed, focused upon on the compact city hypothesis' veracity (whether compaction actually delivers the environmental, social and economic benefits that it is supposed to); feasibility (whether compaction defies the market and can be properly implemented); and acceptability (whether urban compaction will lead to a political backlash from local residents) (Breheny, 1997).

The environmental arguments for the compact city, notably that it 'saves' the countryside from greenfield development and that the number of car trips per person are reduced, have been questioned by empirical evidence. Williams (1999: 172) states that 'recent research in three London Boroughs which had been intensified over a ten year period showed no reductions in car use. Travel patterns were so complex, due to lifestyle shifts such as cross-London commuting and increased journeys for leisure, that no relationship could be found'. Furthermore, the environmental gains made from not developing beyond the urban fringe are often negated by 'the subsequent loss of urban open space that may mean a reduction in ecologically important land, and a loss of space for trees and other greenery' (Williams, 1999: 172). The economic benefits of urban intensification have also been questioned: plans to rejuvenate downtown areas through intensification frequently fail according to Gordon and Richardson, (1997) while there has been little empirical evidence to show that higher population densities lead to economic growth. However, a recent study by Carruthers and

Ulfrasson (2003: 506) across 283 metropolitan areas in the US 'suggests that per capita spending on infrastructure declines at greater densities and increases with the spatial extent of urbanised land area'. Therefore, while some efficiency gains may be possible for the provision of services through increasing population density, the complexity of the whole compact city concept means that in many cases no direct parallel can be easily drawn between economic growth and intensification. Closely linked to whether urban compaction can be implemented are doubts over whether this will be acceptable to local residents. Perceptions of 'over-development' have led to communities feeling that their neighbourhoods are being over-crowded, and are losing amenity. This leads to battles to stave off development, usually on backland sites, or well-loved amenity space such as playing fields or sports grounds (Williams et. al., 1996: 86). Thus, even if urban compaction policies are implemented successfully, they may not be acceptable to large tracts of the population, resulting in the reversal of such policies by locally elected councillors keen to retain their jobs. Breheny (1997: 213) claims that generally, marketing surveys carried out by house-builders reveal a strong preference for houses with gardens and as much space in both as possible, an urban form that contradicts compaction. Moreover, developments requiring shared driveways, smaller units, multiple extensions turning detached houses into terraced housing, and other methods used to increase the density of use among the urban environment, have led to a perceived reduction in quality of building stock, especially in the UK (Williams et. al., 1996). Filion et. al., (1999: 1319) summarise many of these problems by stating that: 'One cannot escape noticing that policies inspired by such criticism of urban sprawl have had little influence on urban

development which remains predominantly low density and car dependent. Proposed corrective measures have been stonewalled by a deep-seated consumer taste for low-density living and by vigorous anti-intensification (**N**ot **I**n **M**y **B**ack **Y**ard) sentiments. Furthermore, even massive transit investment, suburban downtowns, and urban regeneration projects have failed to alter the heavy car reliance typical of suburban forms of urbanisation. (Duany et al 2000).

Clearly, valid questions have been raised in the literature over the past eight to nine years about the veracity, feasibility and acceptability of the compact city as a tool for promoting urban sustainability. Not only has the literature focused on the shortcomings of certain types of urban compaction, but the whole concept of increasing urban sustainability through intensifying activity within a more confined area has been questioned and found wanting. As a result, many researchers have begun to look at new approaches to promoting urban sustainability: if urban sprawl is clearly unsustainable, but urban intensification is only questionably sustainable and riddled with issues and complexities, what methods should be used in the search for a sustainable urban form? (Jenks et. al. 1996) The burning question in most urban sustainability researchers' minds has become whether to focus on finding the best way to implement urban intensification policies, and to monitor their progress with utmost care or whether to abandon the whole 'compact city' concept and instead move towards developing new methods of attaining a more sustainable urban future.

2.7.2 Growth Management

Growth management is generally defined as the regulation of the amount, timing, location and character of development (Levy 2009). Growth management programs are often heavily motivated by environmental considerations. A related consideration may be ensuring a desirable pattern of land development in future years. Preserving an existing lifestyle and community ambiance are common motivations as is ensuring that community facilities such as schools, roads, utilities and recreation will be adequate for future needs. In some cases, a major goal of growth management will be fiscal, ensuring that the community will not be swamped by development imposed costs. Lastly, growth management may have an exclusionary or "keeping the good thing to ourselves motivation" (Levy, 2029).

In general, growth management plans or systems are made up of elements that have been well known to planners for years (Levy, 2009). However, Growth management systems differ from traditional comprehensive planning not in the elements that compose them but in the synthesis of those elements.

Specifically, growth management systems are generally characterized by very close and long- term coordination between land- use controls on the one hand and capital investment on the other. They are often also characterized by the use of more modern approaches to land- use control and often, by a great sensitivity to environmental issues.

When growth management appeared in the late 1960s and early 1970s, several different terms with overlapping meanings came into being. "A review of scholarly

articles published on the field in the 1970s carried, the title management and control of growth. In addition to the terms growth management and growth control, the term no growth also came into use" (Levy, 2009).

Growth management might be taken to mean management without any implication, of limiting growth. Growth control carries the implication that growth is not only to be managed or guided but also to be limited. The term no growth carries the obvious implication of an intent to step growth entirely. With time, growth management became the standard term covering programs that fit all three senses of the terms just noted {Levy, 2009}. The motivation and approach to growth management for any municipality needless to say is highly dependent on the prevailing political, social and economic clime.

2.7.3 Growth Management Case Study: Ramapo, New York

One of the first and best known examples of growth management programmes was that enacted by Ramapo, New York, in 1969. The town located about 28 miles northwest of mid town Manhattan, felt itself on the verge of being overwhelmed by new development. The town was at the very fringe of what was then commuting distance from Manhattan but was in easy reach of masses of new commercial development in the outer portions of the New York metropolitan region located in southern New York State and in adjacent parts of New Jersey. Ramapo was already zoned so that only single-family development was permitted, but it then added rules which made it possible to turn down development proposals that met the zoning requirement if, the development did not have enough points for such infrastructure as

sewers, nearby recreational facilities, public roads and proximity to a firehouse, all items keyed to the town's 18-year capital improvements program. Opponents of the plan saw it simply as exclusionary zoning carried to a new level and took the town to court. On a split decision by the state's appeal court, the town's position was sustained.

2.7.4 Smart Growth

In the middle of the 1990s, the term smart growth appeared on the planning scene and rapidly became the buzz word of the day. The term was first used in connection with the Maryland state plan in 1996. Whether smart growth is inherently different from growth management as just described in section 2.5.2 or whether it is basically growth management under a more attractive name, "who could be in favour of stupid growth is arguable" (Levy, 2009). Much of the concern with smart growth has been driven by a concern with suburban sprawl, a condition that derives directly from population growth. The biggest force behind smart growth in the US has been citizen concern over one aspect of sprawl, namely traffic congestion. The suburban resident who finds that his or her commuting time is increasing because of growing traffic congestion on major roadways and who finds that trips to shopping, to visit friends and to entertainment and recreation are making him or her feel as if the car is becoming a second home is likely to feel that something needs to be done. Often that something is planning for smart growth. Other forces behind the push for smart growth have been concern over perseveration of the natural environment and concern with what some suburban residents may regard as excessive urbanization of their environs (Levy, 2009). Because smart growth does not have a precise definition, the term means

different things to different people, and it is thus a large political tent that can contain many people with different tastes and agendas (Abbot et al in Levy, 2009).

The key elements of smart growth include using land- use controls, tax policy and public subsidies to encourage compact development. Also, the smart growth program places an emphasis on infill development and reuse, whether of old buildings or of previously used industrial or commercial space. A smart growth program might also involve buying up or acquiring development rights for some undeveloped land to assure a supply of future open space and to channel development into selected areas. Urban growth boundaries, such as those used around Portland, Oregon, might be part of a smart growth agenda. Those who favour smart growth are likely to be fans of new urbanism. New urbanist design emphasis relatively close spacing between structures and a fine- grained mixture of land uses. Both of these facilitate trips by foot or bicycle and also reduce the average length of automobile trips.

2.7.5 Urban Renewal and Community Development

Urban Renewal began in the United States with the Housing Act of 1949 and officially ended in1973. The goals of the program, as represented in legislation and congressional debate, include:-

1. Eliminating substandard housing
2. Revitalizing city economies
3. Constructing good housing
4. Reducing de facto segregation

The method used was clearance and rebuilding directed by local agencies and supported by large Federal subsidies. It was and still stands as the largest Federal urban program in US history, and it reshaped parts of hundred of communities.

Congress intended urban Renewal as a housing program, as the goals listed earlier indicated but as time went by, commercial and even industrial development were included as a way of revitalizing and modernizing the economies of the cities where renewal was executed.

A critical concern in any urban Renewal program is the fragmented nature of land holding in urban areas. As a response to this, quite a number of models and strategies have evolved over the years to deal with this concern. These include various land readjustment models like the one used in Japan which Morales (2010) refers to as instigated property exchange. Locally, the overriding public interest clause in the Land Use Act provides a good alternative for overcoming this challenge.

2.7.6 New Approaches and a Focus on Urban Design (The Neotraditionalist Approach)

Most of population growth in cities around the world is absorbed by the suburb. Andres Duany, a leading advocate of neotraditional planning insists that by and large, the suburbs are being planned wrong. He tends to lay the biggest share of the blame on the traffic engineer but still reserves a good deal of blame for the planners. His popular prhase states, highway engineers “want cars to be happy” with the result that there is an over emphasis on planning for the automobile. Meeting traffic flow and

parking goals take precedence over designing for people and for walkable environments. New urbanism faults sub- urban planning for an excessive separation of land uses, particularly residential use from other uses and for laying out land uses at too coarse a grain. The result is that distances between uses become too great for convenient walking and therefore people are forced into excessive dependence on the automobile with all its attendant environmental and health consequences. Neotraditional planning is so called because much of what the neotraditionalists advocate goes back to traditional city and town planning practices that have been rejected in modern suburban planning. Neotraditionalists advocate the planning practices and strategies outlined below.

2.7.61 Mixing of Land Uses at a Fine Grain

Neotraditionalists advocate the mixing of uses at a fine grain. They note that zoning originated to separate incompatible uses but that there is much less need for this technique today than at the turn of the century. For example, much manufacturing today is quite and clean, and there is no reason why it cannot be located relatively close to housing. It is important that buildings in an area be in scale with each other but not that they all be for the same type of use or for the same type of inhabitant. They argue that excessive homogeneity of use and building type leads to sterility and inconvenience.

2.7.62 Pedestrian Friendly Designs

Neotraditionalists place great importance on pedestrian friendly streets. The traditional city street with say, two lanes for traffic, one lane on each side for parked cars and sidewalks is pedestrian friendly. Because it has only two lanes of traffic, which moves at moderate speed, it is easy to cross. The lines of parked cars offer the pedestrian on the side walk a sense of security because there is a barrier between him or her and the moving vehicles in the streets. In this type of design, buildings are brought up close to the street and parking, beyond what can be accommodated on the street should be located behind the building. Neotraditionalists see the typical shopping centre or office park design in which the building is set back and isolated from the street by a large parking lot as a design disaster. Neotraditionalists like alleys, for this permit parking to be placed behind buildings. The alley avoids the need for the typical residential design in which half of the frontage of a house consists of a garage door. A streetscape that consists largely of garage doors is not a very interesting or inviting public space. The neotraditionalists vision of good design necessary implies fairly small lots, for widely spaced houses encourage urban sprawl and discourage walking.

2.7.63 Transit- Oriented Developments

Peter Calthorpe, another leading neotraditionalists is associated with the philosophy of Transit – Oriented development (TOD). His general design philosophy is similar to Duany's although he places somewhat more emphasis on public transportation and the building of sufficiently large, compact down town to support public

transportation. Transit- Oriented Development means a high Density area laid out so that every residential unit within it is within ten minutes walk of a transit stop. A series of these "pedestrian pocket" developments strung out along a transit line would give the line sufficient rider ship to divert a significant number of trips from automobiles, to buses or light rail.

2.7.64 City of the Future

The urban designer is concerned with the development of the city not only in the present but also 15 to 20 or more years into the future. For that reason it is important to have some concept of what cities in the future might be like. These ideas are as visionary as they are radical and somewhat controversial.

i. Le Corbusier's Ville Radieuse (The Radiant city)

Le Corbusier envisioned high-rise residential towers in a parklike setting. Major roadways would link together sectors of the city. Two of his key ideas are reflected in this urban design proposal. The first stemmed from his idea of returning the land for human use. It is for this reason that his buildings are raised off the growth with colunms or pilote, in this way buildings are not barriers to human movement along the ground. The second idea is how the organization of the city should change if we were to accept the automobile. Major roadways connected the high-raise housing with commercial and industrial sectors of the city. Le Corbuser's idea seeks to find ways for people to be in closer contact with nature.

ii. Frank Lloyd Wright's Broad Acre City

The idea of the Broad Acre City revolves around a concept that would have each individual or family own a 1- acre lot (10m x 10m) to be used for residential purposes. Homes and industry would be connected by major roadways. Wright felt that individual ownership of land by broad segments of the population was important in preserving a democratic society. His political and social philosophies, very much different from Le Corbusiere's (that advocates community ownership of land) were translated into the design proposals contained in the plans for the Broad Acre City.

iii. Paolo Soleri's Hyper Structure

Paolo Soleri holds a very radical and somewhat controversial concept of the future city (Levy, 2009). Drawings and models by Soleri depict magastructures with heights as great as the tallest skyscrapers but covering as much as several hundred acres of ground. The structures contain both housing and employment for a population of 100,000 or more.

Soleri has labeled this general set of studies "arcology". Like ecology, which is the study of animals in their natural homes, arcology is the study of how best to build urban structures to accommodate homes, manufacturing and public facilities in a fashion compatible with nature. In addition to suggesting new ways of organizing living space, Soleri's proposals contain predictions of completely automated manufacturing facilities that might be placed underground. Soleri constructed a small new community called Arcosanti in the desert north of Phoenix, Arizona to test on a very small scale, some of the concepts embodied in his mega-structure designs.

2.80 INSIGHTS AND CONCLUSION

The literature review has provided insights into the concept of urban sprawl. It clearly established that sprawl as an urban phenomenon is not necessarily engendered by lack of planning but actually in most cases a direct product of planning intervention and policies making it a rather controversial subject among planning professionals and policy makers. The causes of sprawl however vary from region to region, country to country and city to city.

Today, there are three facets of concern as relate to the effects of sprawl and they are; environmental, economic and social concerns. The scale of these concerns however is dependent on local priorities and policies that vary from city to city. Added to these concerns is also the fact that sprawl has its proponents just like it has its opponents.

The concluding part of the literature review clearly identified existing and tested strategies for combating sprawl. It must be said however that when it comes to sprawl, there is no one-size-fits-all solution. Solutions are dependent on local priorities and policies.

CHAPTER THREE

METHODOLOGY

3.0 Introduction

This chapter establishes the conceptual framework and methodology of the research. It is divided into three sections. The first section discusses the conceptual framework of the study. The second section dwells on the data needs of the research and the sources from which the data was obtained. The third and last section presents the data analysis techniques and how the conceptual framework is applied in carrying out the research.

3.10 Methodology of the Research

3.12 Designing the Integrated Sprawl Analysis Tool

The logic in the integrated sprawl analysis tool is the dynamism it brings to the quantification of sprawl indices, sprawl pattern and the simulation of sprawl implications within one unified medium by utilizing data collected on varying spatial and temporal scales. The ability to manipulate spatial data in one medium is the second logic in the tool design. The demand for a unified tool is based on the limitations of existing techniques which as shown, are limited to the treatment of one or at most two aspects of a spatial phenomenon at a particular instance. The use of Shannon's Entropy for instance to compute sprawl almost always falls short in sprawl pattern analysis and cannot be used in projecting sprawl implications. The shortcomings of the techniques of GIS and Remote Sensing lie with the lack of computation capacity to determine sprawl indices. The integrated framework rather, enables cost effective acquisition of time series spatial data to enable mapping, pattern

analysis and simulation of the implications of sprawl including the computation of sprawl indices. In such an environment, it is easy to undertake sprawl pattern analysis, simulation of sprawl implications and computation of entropy for the different units of analysis over different time epochs.

The technical design of the integrated tool is shown in Fig. 1. Five component parts are recognized. The first is the utilization of Remote Sensing techniques and capabilities in the acquisition of digital spatial data (satellite images) at varying spatial and temporal scales. Stage two is the transmission to, and recording of the Remote Sensing data in a suitable GIS software environment. In this form, the Remote Sensing data is subjected to a series of pre-processing operations (which include geo-referencing, image extraction, geometric correction and image classification) preparatory to the mapping of different land cover categories. In the study of sprawl, only two classes of land cover are required, and they are developed and undeveloped land. This way, insight into the evolved pattern of sprawl can be obtained through pattern analysis. Computation of area coverage and development density statistics for the two digitized themes (i.e developed and undeveloped land) within the spatial unit of analysis (the urban area boundary as delineated into smaller component units) is the third component. This is permitted by the use of 'map calculator' and the 'measure area' and 'measure distance' modules common in most GIS software. The computation of sprawl indices (entropy) using the area and density statistics derived from the previous stage is the fourth component. It is the linking of sprawl indices and mapped patterns that provide useful insights and explanations on the evolution of sprawl. The fifth and final stage of the integration is the exploration of scenarios using

the mapped data in the GIS environment to simulate the implications of sprawl. This is permitted with accuracy, little effort and time spent using the modeling, measurement and map calculator modules in GIS.

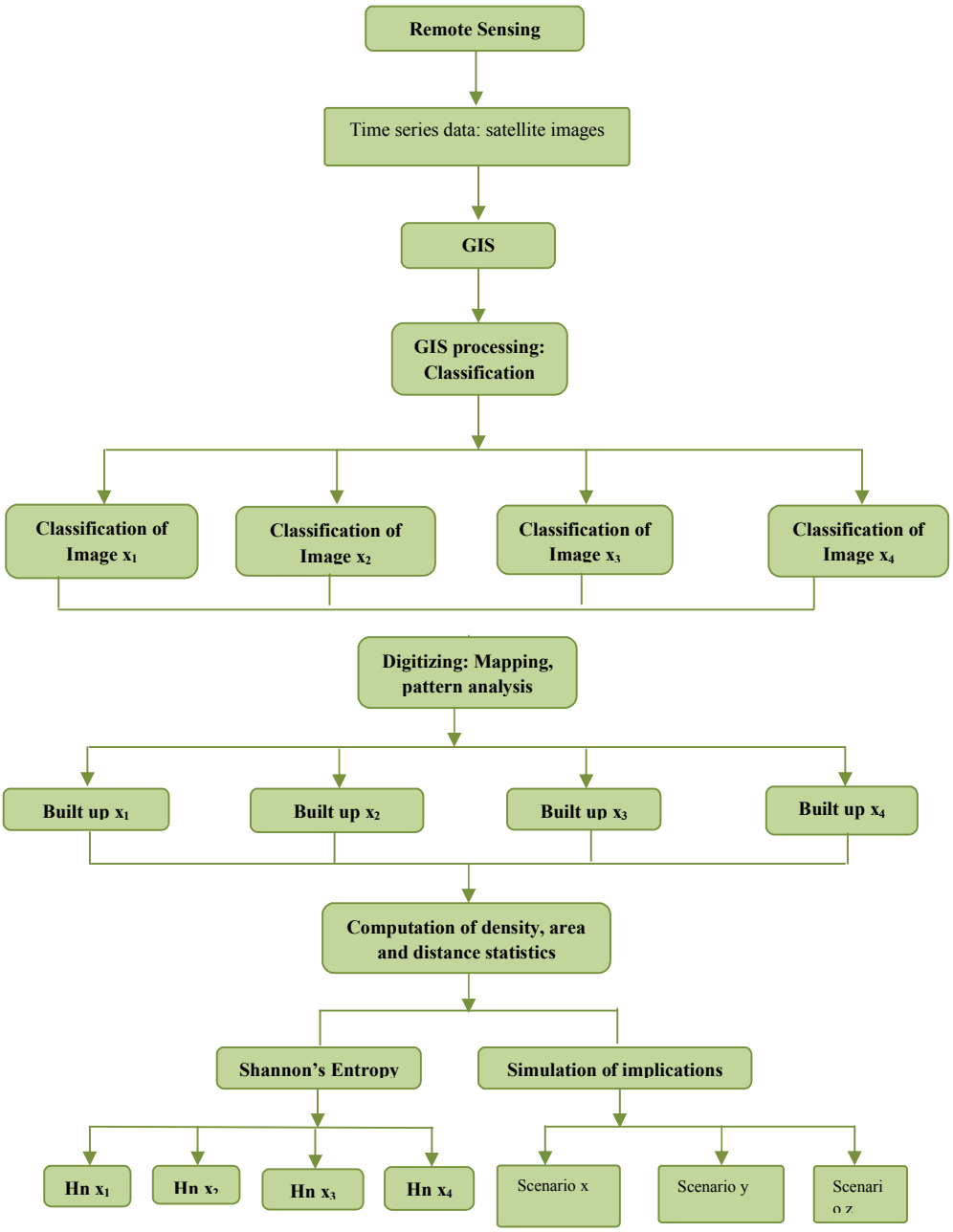


Fig. 1 schematic representation of the integrated tool of sprawl analysis

3.20 The Methodology of Application

To understand the complexity of a dynamic phenomenon such as urban sprawl; land use and land cover analyses, mapping of urban sprawl pattern and computation of sprawl indicator indices need to be carried out. Urban sprawl pattern over the period of four decades (1973-2008) was determined through spatio- temporal analysis of the growth pattern of Kaduna metropolis using visual interpretation, classification of satellite images of the city (over the four different time periods: 1973, 1991, 2001 and 2008) and mapping of the built extent of the city. The standard process for the analyses of satellite imagery such as extraction, restoration, classification and enhancement is applied. The maximum likelihood classifier (MLC) was employed for the image classification. This enabled the area under built-up theme to be recognized and the whole built - up themes for the different satellite image scenes were recognized and digitized; this is to give the extent of the urban area for the particular year the imagery was acquired. The next stage is the stage at which the spatial analysis capabilities of GIS were utilized in computing the total area (in km^2) of all the built up themes for the different time epochs and the total area of the spatial units of analysis. Development densities for each time epoch are also computed using the results from the area computations. The urban sprawl indicator is then computed for each unit of analysis for the different time epochs using the entropy approach with the results of the area and density computations as input data.

The second core objective of the research is to simulate urban management implications of sprawl in Kaduna metropolis. To achieve this, the GIS spatial analysis capabilities are again utilized to compute the total area of development outside

approved layouts, simulate the cost of providing infrastructure and services to sprawled districts and computation of the annual rate of growth of the city.

3.20.1 Data Needs and Sources

Table 1 below shows the data utilized in the research and the sources from which they were collected. Item 1 on the table is the toposheet of Kaduna at a scale of 1:50,000 that was obtained from the Nigerian Defence Academy, Kaduna. The second item which is the NigeriaSat 1 satellite image scenes of Kaduna for 1973, 1990 and 2001 at 32m resolution were obtained from the National Centre for Remote Sensing Jos, Plateau State. The Kaduna Metropolitan map at a scale of 1: 50,000 showing approved layouts and development plans (item 4 on table 1) at scale 1:50,000 was sourced from the Kaduna State Urban Planning and Development Authority (KASUPDA). Google Earth satellite image scene of Kaduna (item 3 on table 1) for 2008 was downloaded via the Google earth server in different scenes and then geo-referenced to create a composite image of the city. Lastly, the rates and charges on land administration services shown on the table as item 5 were obtained from the Ministry of Lands and Surveys handbook on land administration services. Cost of transportation shown as item 6 on the table was obtained through field investigation which proceeded by taking samples of the amount paid for trips between three sets of origins and destinations in the city, calculating the distances covered and computing the average price paid per kilometer of travel.

Table 1Data requirement and sources

S/N	DATA TYPE	SOURCE
1	Toposheets of Kaduna at 1:50,000	Nigerian Defence Academy, Kaduna
2	Landsat images of Kaduna @ 32m resolution for 1973, 1990,2001)	National Centre for Remote Sensing, Jos Plateau State
3	Google Earth scenes of Kaduna @ 15m resolution for 2008	Google Earth Inc.
4	Map of Kaduna Metropolis showing approved Layouts and Development Plans	KASUPDA
5	Rates and charges on Land Administration Services	Min. of Lands & Surveys Handbook on land administration services
6	Transportation costs within the city	Field observation
7	Population Data	National Population Commission

3.20.2 The Analysis Process

The Shannon's Entropy is the technique of choice for the quantitative analysis of sprawl and is easily adaptable to the time-series approach employed in this study. To obtain the value of Entropy, the area (in km^2) of the planning radius (40 km measured at the Leventis roundabout) of the city of Kaduna (which is the delimiting boundary of the officially designated Kaduna urban area) was computed using the "measure area" module in ArcGIS 9.2. The circle is then divided into quadrants (see fig. 2 below) and the area of each quadrant is measured. The 40km planning radius was employed in this study as the defined urban limit of the city in the absence of reliable and updated maps showing the constituent wards and districts that make up the city. In quantifying sprawl, there are two measures, development density and total area of spatial unit within which sprawled is being measured. By dividing the circle of 40km radius into quadrants, the challenge of lack of properly defined spatial units of analysis was surmounted.

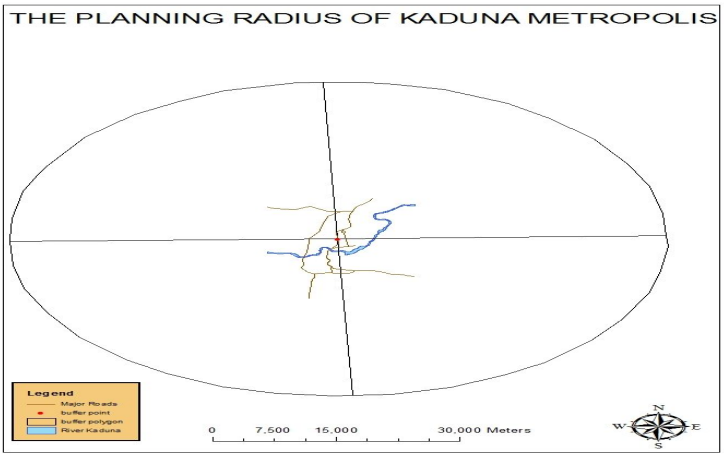


Fig. 2 Kaduna Planning Radius divided into equal quadrants

This is followed by the computation of the area (km^2) of the built-up theme for each quadrant at the four different time epochs as digitized from the classified satellite images; this was also achieved using the measure area module in ArcGIS 9.2. The development density (a measure of the proportion of what is built up compared to the total area of the planning radius) for each quadrant at each time epoch was then calculated and then substituted into the equation as ***Pi*** with ***n*** (a constant) the total number of spatial units (in this case the four quadrants). Repeating the procedure outlined above for every time epoch results in the computation of the magnitude of sprawl denoted by *Hn* (The Entropy value). The result derived for the four time epoch enabled the analysis of the trend and intensity of sprawl at different periods in the evolution of Kaduna. The quadrant with the highest or the lowest magnitude of entropy at any given epoch can be easily identified. The interpretation of the entropy values derived gave useful insights into the pattern of land development at different periods of time in the development of the city of Kaduna. The measure area module is again used to measure the area of the total built extent of the city at the four different

time epochs and the area of the portions of the city categorized under Government approved layouts and DPs. This enabled easy computation of the proportion of the city's built extent that is within or outside Government approved layouts. Having all this data in an automated environment made possible scenario development like simulating the cost of extending infrastructure and services to unserved locations, computing average transportation costs for trips within the city, annual rate of urban growth and revenue accruable from ground rent and other land and physical development related taxes and levies.

3.20.21 Computing the total built-up area of the city and the total area under approved layouts and development plans

As earlier described in under section 3.4.1, by digitizing the area recognized as the built up theme, it was possible to automatically compute the area under that theme using the "*measure tool*" in ArcGIS. Using the same approach, the area under built up that is part of existing approved layouts and Development Plans was computed.

3.20.22 Simulating the cost of extending infrastructure and services to sprawled areas

To simulate and estimate the cost of providing infrastructure and urban services, the same measure tool was used to compute distances (albeit as the crow flies) between the trade fair village layout, (a patch of detached development at the extreme north of the city) and the Kaduna Water Works in Barnawa at the southern part of the city.

3.20.23 Simulating Revenue Loss from Ground Rent, Premium, Searches and other Rates/Charges

Once the total area (in km^2) of the built extent of the city and the total area under approved Development plans (DP) and Layouts was known, the result of the difference between the two gave the total area of the built extent of the city that is not under approved DP's and layouts. Assuming an average lot size of 1500 m^2 as a standard in all Government approved DP's, it was then possible to estimate the total number of plots in the built up theme that is not part of approved DP's and Layouts. Multiplying the total number of plots arrived at earlier with the average ground rent charged (₦70, 000 according to the Kaduna State Ministry of Lands Handbook on Land Administration) gives an estimate of the amount of revenue realizable annually.

CHAPTER FOUR

SPATIO TEMPORAL ANALYSIS OF SPRAWL IN KADUNA AND SIMULATION OF IMPLICATIONS

4.00 Introduction

In recent years, a lot of thrust in this field has been to understand and analyze urban sprawl pattern. The common approach is to consider the behavior of built-up area and population density over the spatial and temporal changes taking place and in most cases the pattern of such sprawls is identified by visual interpretation. However, in order to achieve sprawl pattern identification visually, the area under study has to be observed at different spatial and temporal scales. This is made possible by the availability of dated and recent satellite imagery at relatively good resolutions that enabled visual analysis and interpretation. In this chapter, satellite images at different temporal scales were used to facilitate a time series analysis of the spatial and morphological transformation of the city of Kaduna between 1973 and 2008. The explanations for the pattern established in each time epoch is also given in the four sections that constitute this chapter which are a representation of the different time epochs considered by the study and the chapter concludes by reporting the attempts made at simulating the urban management implications of sprawl using the Integrated Sprawl Analysis Tool.

4.10 Sprawl Pattern – 1973

The main objective of the spatio-temporal analysis was to establish the growth dynamics of Kaduna based on sprawl indices computation between 1973 and 2008. The total built-up area of the city in 1973 was approximately 70.98 km^2 and entropy values as computed for the four quadrants shows that the quadrant with most dispersed development, and hence the highest value of entropy is the North-East (NE) quadrant with a value of 0.13 (see table 2). This suggests that the highest rate of urban sprawl in Kaduna at this period occurred in the North-East quadrant. By then, Kaduna could be said to be a city comprising of essentially two townships, one to the north consisting of the Government area and the city centre, Tudun Wada, Sabon gari and Kawo and the other to the south comprising the railway reservation, Barnawa, Makera and kakuri. This created an easily identifiable pattern of leap-frog patches of development that defined the city's built form (see figs. 3&4).

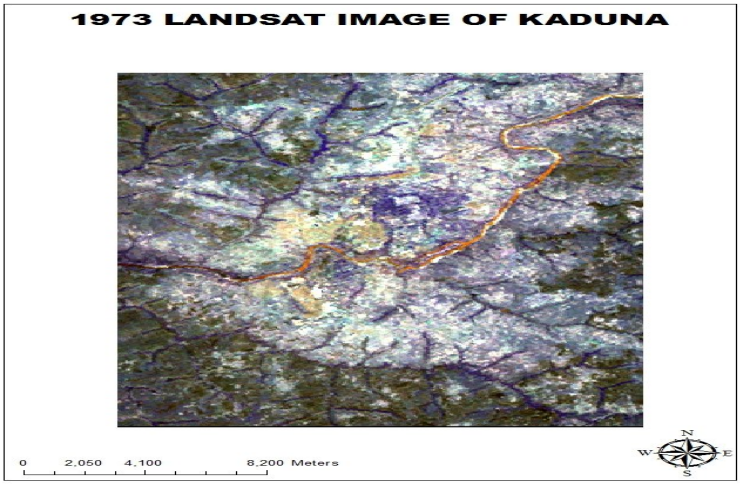


Fig. 3 1973 Landsat 32m Resolution Image of Kaduna

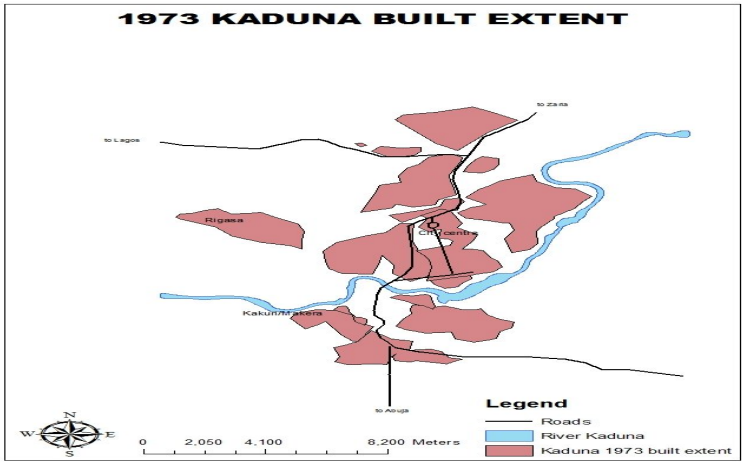


Fig. 4 Kaduna 1973Built Extent

The leap frog pattern of development at this early stage of the city's development is attributable to the early history of the city. That is, the British colonial founders of the city had intentionally planned the city to be made up of three distinct townships: the European area housing the government offices and residences for the colonial officers; the Tudun Wada originally a labour camp meant for the natives of northern origin; and the Sabon Gari which was designated for the southern natives that had come along with the British Military or migrated afterwards. Later on, the survey and railway stations as well as the industrial developments in the villages of Kakuri and Makera were added to the urban landscape. These are all detached masses of development.

Table 2 Entropy for 1973

Quadrant	Entropy (Hn)
North West	0.06
North East	0.13
South East	0.07
South West	0.06

4.20 Sprawl Pattern – 1991

Between 1973 and 1991, the population of Kaduna increased by 58.60% jumping from 448,395 persons to 711,155 persons (NPC, 2006). This astronomical rise in population translated into accelerated and unprecedented urban expansion during this period and the city's built fabric expanded to a much greater size (124.43km^2) than it was in 1973. The entropy values between 1973 and 1991 increased from 0.06 to 0.12 for the North-West quadrant and from 0.13 to 0.20 for the North-East Quadrant. In the South also, Entropy values for the South-East and South-West quadrants jumped from 0.07 to 0.10 and 0.06 to 0.18 respectively. These increases are easily explained by the sprawl pattern analysis on the digitized built extent of the city shown in fig. 6 as derived from the classified satellite image of the city for 1991 shown in fig.5.

Table 3 Entropy for 1991

Quadrant	Entropy (Hn)
North West	0.12
North East	0.20
South East	0.10
SouthWest	0.18

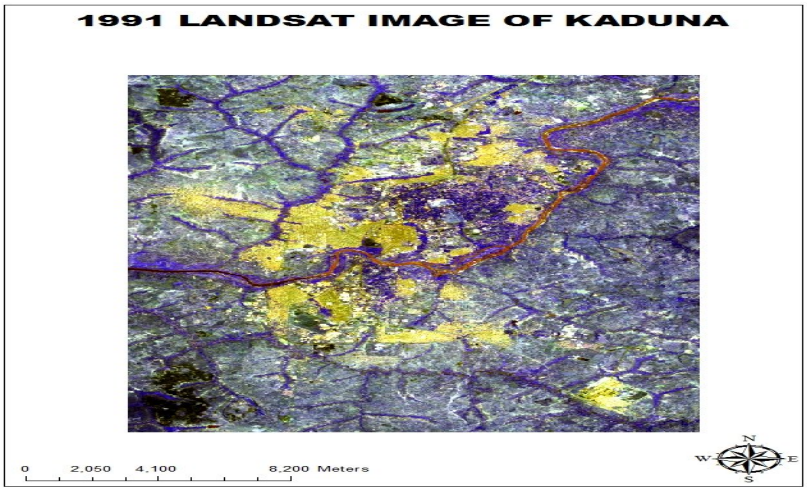


Fig. 5 1991 Landsat 32m Resolution Image of Kaduna

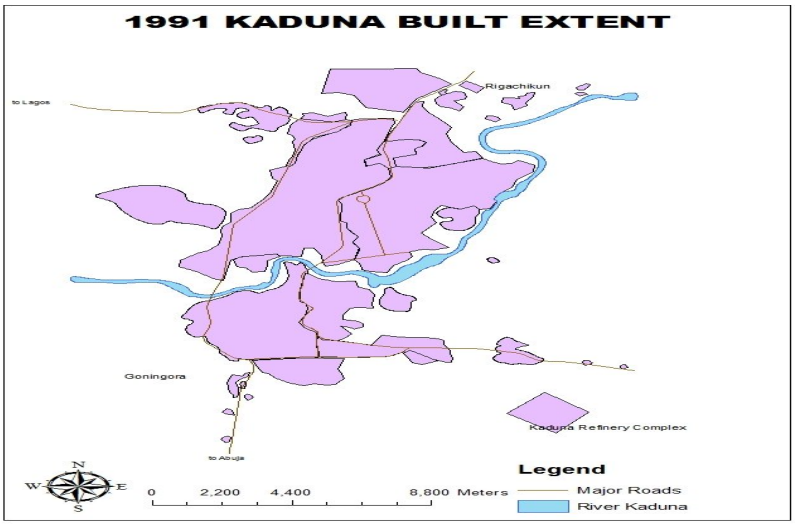


Fig. 6 Kaduna 1991 Built Extent

Most of this expansion was in the northern sector where the Sabon Gari, Tudun Wada and even parts of the government reservation areas had greatly expanded. Added to that, the areas around the Nigerian Defence Academy, Kawo, Abakpa and Mando also witnessed tremendous expansion. The industrial suburbs of Makera and Kakuri established years back were growing at an appreciable rate. Added to that, the

expansion of the village of Barnawa and the emergence of the low income neighborhoods of Television, Narayi and Sabon Tasha (as a result of the establishment of the Kaduna Refinery) ensured sustained urban expansion south of the Kaduna River.

4.30 Sprawl Pattern – 2001

By 2001, entropy values for the South-East and South-West quadrants rose slightly from 0.10 to 0.16 and 0.18 to 0.20. At this epoch, the total built-up area of the city was 142.24 km^2. In the North, the value of entropy for the North-West rose marginally from 0.12 to 0.13; and declined from 0.20 to 0.19 for the North-East quadrant. The growth pattern analysis of the digitized built extent of Kaduna shown in fig. 8 (as derived from the satellite image in fig. 7) shows that most of the urban growth in Kaduna during this period was limited to the infilling of spaces between the hitherto distinctly identifiable urban districts in both the northern and southern sectors of the city. Some peripheral expansion however occurred in Gonin Gora up towards Kakau along the Abuja road around the refinery complex and particularly in Romi and Sabon Tasha along Kachia road. This explains the decrease in entropy in the northern quadrants and the somewhat marginal increase in the southern quadrants.

Table 4 Entropy for 2001

Quadrant	Entropy (Hn)
North West	0.13
North East	0.19
South East	0.16
South West	0.20

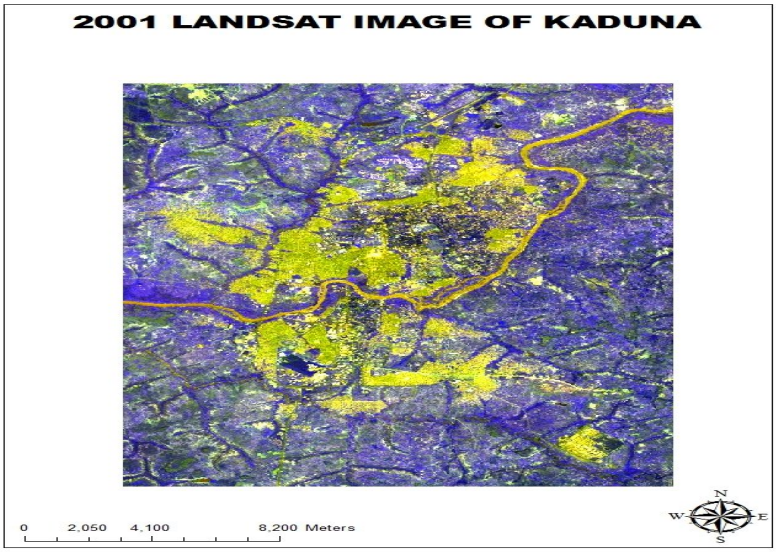


Fig. 7 2001 Landsat 32m Resolution Image of Kaduna

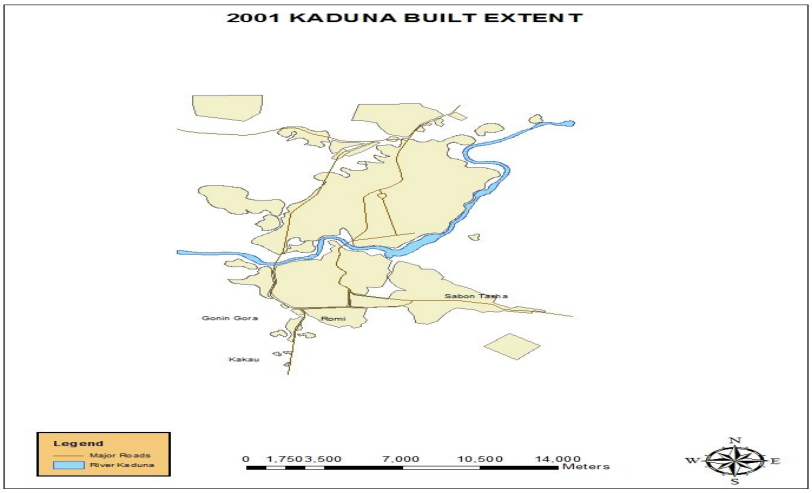


Fig. 8 Kaduna 2001 Built Extent

4.40 Sprawl Pattern – 2008

Between 2001 and 2008, significant increases were recorded in the value of Entropy as can be seen in the leap from 0.13 to 0.20 for the North-West quadrant; 0.19 to 0.23 for the North-East quadrant; 0.16 to 0.20 for the South-West quadrant; and 0.20 to 0.21 for the South-East quadrant. By 2008, the total area of Kaduna's built fabric is approximately 164.00 km^2. At this time, a ribbon pattern of sprawl had fully developed North-South with the city spanning approximately 32 km on the North-South axis along the Abuja- Kaduna- Kano regional arterial as compared to the 13.5 km on the east-west axis (see figs. 9 & 10).

Table 5 Entropy for 2008

Quadrant	Entropy (Hn)
North West	0.20
North East	0.23
South East	0.20
SouthWest	0.21

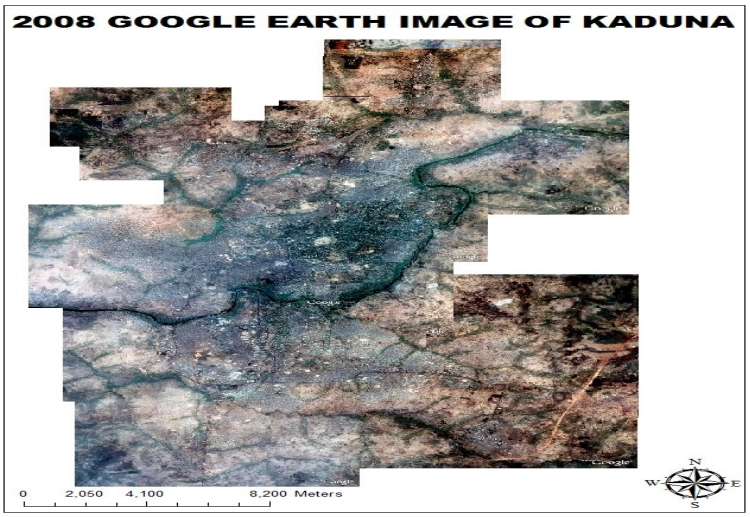


Fig. 9 2008 Google Earth Image of Kaduna

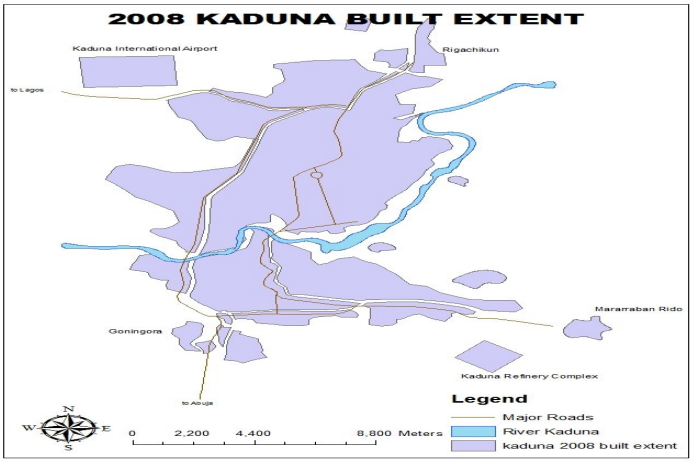


Fig. 10 Kaduna 2008 Built Extent

This form suggests a continuous dispersal of development but at the same time infilling of the spaces between the scattered patches of development especially along the roads linking them. A further outward expansion is also seen as isolated masses of development along Kachia road; the area known as Mararraban Rido in the south; the area around the Kaduna airport and the southern extremes of Rigachikun. The emergence of development at Barakallahu along the Zaria road almost opposite Rigachikun and patches of growth along the Abuja road especially around the Kakau interchange are other growth axis.

4.50 Summary of Findings

On the whole, a critical look at the entropy values reveals sprawling in the different quadrants of the city over the time epochs under consideration. It is worthy of note to state that there is a variation in the intensity of sprawl for the different quadrants at different periods, but an upward trend appears predominant as can be seen in fig. 11 below.

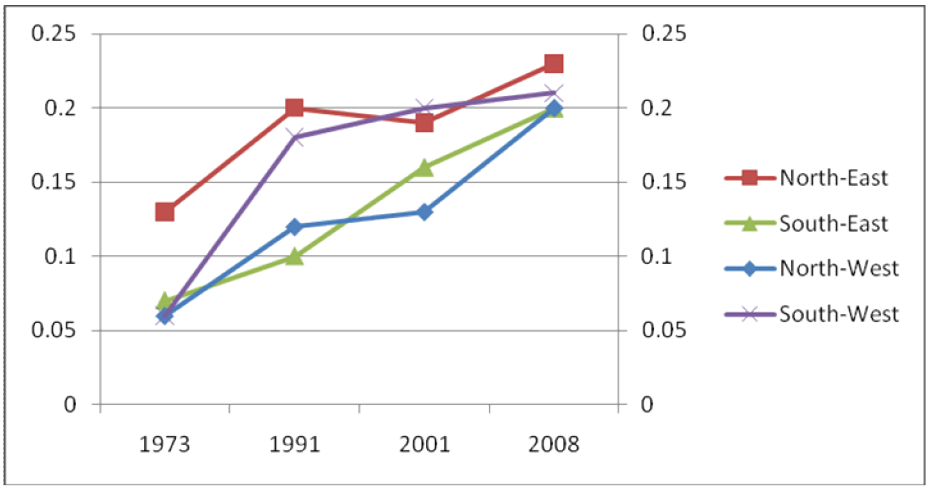


Fig. 11 Entropy variation between 1973 and 2008

The North-East quadrant stands out with the highest values of Entropy at 0.13, 0.20, and 0.23 for 1973, 1991 and 2008 respectively. It only fell behind to the South-West quadrant by 0.01 in 2001 when it posted an Entropy value of 0.19. This had earlier been explained by pattern analysis as a period that was characterized by very little outward growth and more of infill development. Second ranked is the South-West quadrant with Entropy values of 0.06, 0.18, 0.20 and 0.21 for 1973, 1991, 2001 and 2008 respectively. The last ranked quadrant in terms of sprawl intensity is the North-West quadrant which posted Entropy values of 0.06, 0.12, 0.13 and 0.20 for the epochs 1973, 1991, 2001 and 2008 respectively. By and large, looking at the total picture as depicted by the analysis, there seems to be an increase in Entropy from the base year all through the subsequent epochs. This sprawled pattern is attributable to first and probably most importantly population increase and secondly the existing pattern of urban growth in Kaduna which is largely dispersed.

4.60 Simulating Urban Management Implications of Sprawl

(a) Estimating the Cost of Servicing the City

To meet the second objective of the study, an attempt was also made to simulate the cost of extending portable water (with distances taken as the crow flies) to three unserved outlying areas of the city using the integrated tool. The results are shown in table 3 below. By the figures established, it will cost the Kaduna city authorities in 2010 over ₦3, 000,000,000 (Three billion Naira) to install pipe networks (only) that will supply water to three (shown in fig. 12) out of the numerous suburban districts in Kaduna. Extending urban services like water, electricity, refuse collection and civil infrastructure to the areas that have experienced a combination of leapfrogging and linear sprawl can be quite daunting and will most certainly present some peculiar challenges. As shown by the statistics, sprawling districts pose problems of consumer diseconomies to a city as regards the extension of infrastructure and services to outlying developments. This is by increasing the cost per population served.

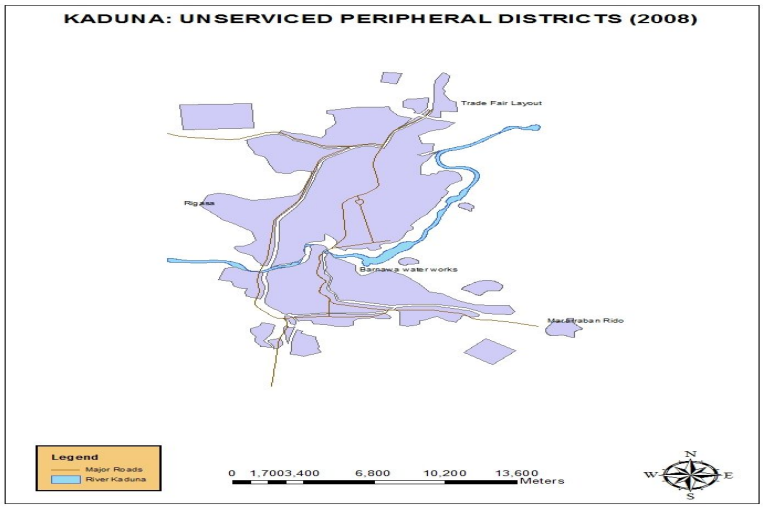


Fig. 12 unserviced peripheral districts

Table 6 Cost of extending water distribution pipes to three peripheral locations

S/N	PERIPHERAL AREA	DIST. FROM WATER WORKS	RATE/500m of PIPING IN ₦	TOTAL AMOUNT IN ₦
1	Trade Fair Village Layout	19.70 km	35,696,700*	1,406,449,980
2	Mararraban Rido	11.61 km	35,696,700*	828,877,374
3	Rigasa	12.87 km	35,696,700*	918,833,058
	TOTAL			**3,154,160,412.00**

**Source: Kaduna State Water Board*

(b) Projecting Land Based Revenue

Through the tool, an attempt was made to project land based revenue accruable to Kaduna. The finding is that approximately 94.86 km^2 representing about 58% of the 164.00 km^2 that is the total built fabric of Kaduna as at 2008 lies outside approved layouts and development plans. This translates into a huge loss. On ground rent alone, the annual revenue loss was estimated at ₦4, 426,800,000.00 (Four Billion Four Hundred and Twenty Six Million Eight Hundred Thousand Naira Only). This is at the

current average rates of approximately ₦70, 000 for a 1500m^2 lot. This unusual loss of revenue is a strain on the city's financial base and a setback on the provision of basic infrastructure and services.

(c) Establishing the Quality of Development Control

The third attempt using the tool is to establish the proportion of the built fabric of Kaduna under formal planning control. This was achieved using the "mapping" and "measure area" functions of GIS (an integral component of the tool) to map and compute areas under formal planning control as derived from a map of Kaduna (fig. 13) showing government approved layouts. The remainder of the built up area not under the first category was then computed as the total area of development outside formal planning control. The statistics available from the procedure described above shows that only a paltry 42% of the urban land is under approved and gazette development plans. This portends danger for effective land administration and management. If land is to play its role as a veritable asset and commercial commodity that can be used as security and collateral for loans and mortgages, then its management and administration must inspire the requisite confidence.

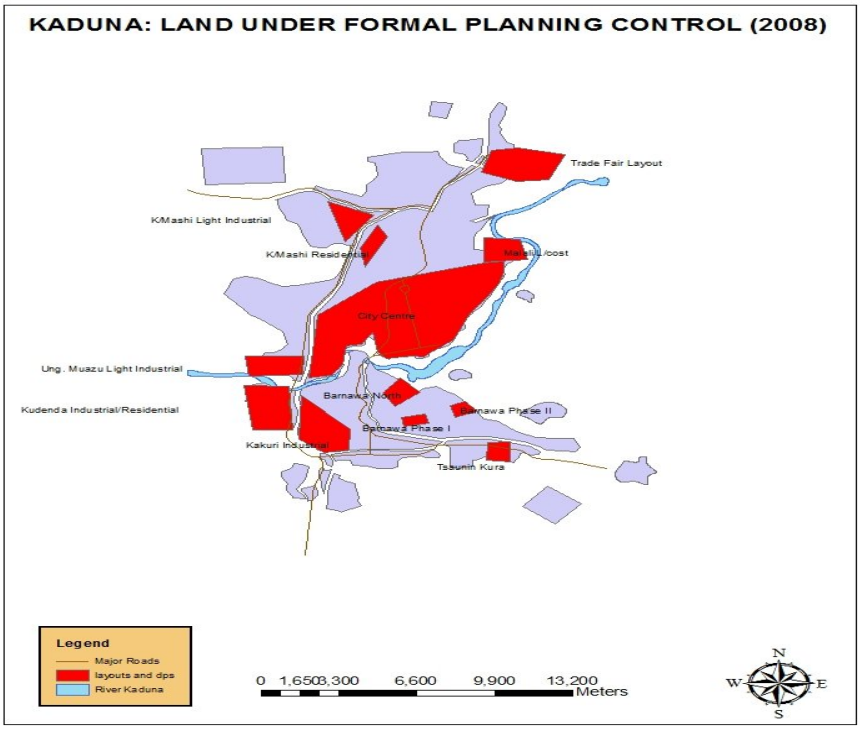


Fig. 13 Approved layouts and Dps

(d) Computing Urban Growth Rates for Kaduna

The application of the tool in computing the rate of urban growth for Kaduna was also achieved in this study. This was done by employing the mapping, measure area and map calculator modules of the tool in computing the area statistics of the built extent of the city for the four epochs. The difference in area of the built extent between one epoch and the preceding one was computed and from the statistics, it was possible to estimate an annual growth rate for Kaduna put at an appreciable 2.66 km^2. This excessive physical growth rate is most likely to result in further sprawling with all its attendant implications as there is no reason to suggest that growth will be in any other form or pattern. Furthermore, if the current rates of population increase and physical

expansion are sustained, Kaduna is likely to double its size in spatial extent in the next 50 years.

(e) Simulating Transportation Costs

In simulating the cost of transportation in the city, the rate per kilometer as charged by commercial transport operators was used. The tool was then used to measure the actual distance between a known origin and a destination that represent the typical routes plied by an average commuter. To illustrate this, the route between Rigachikun and the Leventis roundabout in downtown Kaduna was used. The journey as measured covers an approximate distance of 17 km. At an average rate of approximately N6 per kilometer, the amount charged adds up to N100. Therefore, a commuter that resides in Rigachikun and works in the city centre spends an average of ₦200 to get to work and back home on a daily basis. This translates into an unhealthy sum of ₦6, 000 a month in a city where the Government approved minimum wage is ₦7, 500. Owners of personal automobiles also have to travel long distances to and from work and also to visit important activity areas within the city because average distances between destinations in the city are relatively long. Residents of Rigasa, Sabon Tasha, Trade Fair Complex and Gonin Gora for example are separated from the city centre by an average distance of 20km (distances measured "as the crow flies").This translates into substantial sums of money on maintenance and fuelling of personal automobiles.

CHAPTER FIVE

LESSONS DRAWN, RECOMMENDATIONS AND CONCLUSION

5.00 Introduction

5.10 Lessons from the Study

A number of positive lessons were drawn from the approach employed in quantifying sprawl in Kaduna. First, the utility derived in the integration of GIS, Remote Sensing and Entropy made statistical computations of area cover, density and sprawl faster and less tedious. Secondly, it is possible through this approach to undertake scenario modeling and planning which provide the ability to simulate the implications of sprawl with higher degree of certainty. Also, it has been established that the approach is highly cost effective utilizing freely available low resolution satellite imagery from Government sources and Google Earth. This will go a long way in reducing the cost of mapping for municipal authorities to almost zero. The exorbitant cost of mapping is often blamed for the inability of city authorities to monitor and control urban expansion effectively.

On the other hand, the drawback is the dearth of reliable and updated spatial data in the form of administrative maps at most urban levels in Kaduna. The lack of these maps prevented the computation of sprawl indices (Entropy) at the ward or district levels of the city which would have given higher levels of precision and accuracy. In the experience of Kaduna, the positive results are shown to be consistent with the assumptions at the onset of the study. This is because the application of the tool in sprawl analysis in Kaduna has shown that it is actually workable and viable to

integrate GIS, Remote Sensing and Shannon's Entropy into one analytical framework capable of producing superior results not achievable if the three were to be employed as stand-alone techniques of sprawl analysis. These superior results are evident in the fact that the application of the tool in Kaduna enabled time-series analysis, sprawl indices computation, pattern analysis and simulation of sprawl implications concurrently.

5.20 General Recommendations

Because of its versatility, it is recommended that urban planners and managers interface remote sensing, GIS and the Entropy in the mapping of growth, sprawl and simulation of implications. As shown from the study, not only will there be value from the precision of the tool but the saving of time in the analysis allows proactive response to urban management issues. To draw value from the methodology, the basic constraints to its adoption need to be removed. In most planning offices, the equipment and personnel base to utilize the method is lacking. The constraint of lack of capacity can be removed through training and education. Secondly, there is an urgent need for government as represented by its agencies to improve mapping at suitable spatial scales and also improve the generation and archiving of other data types. This will facilitate effective research and formulation of robust urban management and development control strategies.

5.30 Recommendations for Kaduna

It is recommended that the Kaduna State Urban Planning and Development Authority (KASUPDA) leads the adoption of the tool in Kaduna by creating an urban growth analysis and monitoring unit within the existing structures of the Board. This unit will engage departments and units within the board and other ministries in carrying out the periodic analysis of urban growth and the dissemination of the information gathered to public and private organizations that have use for it. Examples of organizations with need for such information include utility providers, property developers, telecommunication providers, security agencies, fire department, the Health Ministry, and the Education Ministry. From the outcomes of the research, the tool will be beneficial to Kaduna in the following ways:

(a) Accurate Estimation of Land Based Revenues

The Integrated Tool of Sprawl Analysis as has been demonstrated in this study has the capability to simulate accruable land based revenues. The information derived from the simulation when fed into the process of revenue collection can be invaluable as the city authorities can now tell what is collectable and from whom at any particular point in time. This will help fashion effective strategies in revenue generation, aid in reducing leakages and improve the overall revenue profile of the city.

(b) Planning of Infrastructure and Urban Services Delivery

The ability of the tool to simulate the cost of providing urban services and infrastructure can be very useful in the process of infrastructure planning, budgeting and prioritization of interventions based on the objective identification of areas of

greatest need within the city. The rapid assessment of the dynamics of urbanization will also assist the development of proactive measures for providing infrastructure and services rather than the usual reactive approach of waiting until there is a gap to be filled which has been shown to be extremely inefficient.

(c) Planning and Growth Management

In Kaduna, planning and development control is greatly hampered by the dearth of data especially up to date maps seen as cardinal requirements that determine the effectiveness and success of these activities. The tool will provide fast and convenient access to updated mapped data and will also facilitate regular updates that will enable concerned authorities keep up with the pace of urban growth and development. This will have a positive impact on planning and growth management efforts.

(d) Stakeholder Mobilization for Development through Advocacy

Urban planning and management decision-making process in Kaduna is very diffuse. It is spread widely among various government agencies, field practitioners and policy makers and is not easily captured in a single decision-making platform. This makes it pertinent to devise a model where all stakeholders will work under a common jurisdiction. For all these actors to be carried along, an efficient system that is capable of collecting accurate and reliable data and at the same time communicating it to those involved in decision making through an efficient medium is required. The rapid mapping, update and visualization capabilities of the tool will help achieve the noble objective of engendering participatory planning and improving the quality of decisions in governing the city.

The constraints and limitations to the adoption of the tool are three: lack of technical know-how, lack of equipment and lack of managerial support. To address these issues, the following are suggested:

(a) Skill and Education

Staff require training and education to enable them attain the minimum level of expertise and competence needed for the effective deployment of the tool in Kaduna. Suitable candidates for this type of training are highly motivated middle cadre staff with Degree level education in Urban and Regional Planning, Cartography, Remote Sensing and Land Surveying.

(b) Equipment (Computer Hardware and Software)

The necessary hardware and software need to be acquired. Two properly calibrated computer workstations, one handheld GPS unit, ArcGIS 9.2 software, Google Earth Software, other conventional software needed for the proper functioning of the workstations and a reliable internet link are required as the initial investment.

(c) Managerial support and Goodwill

The management of KASUPDA needs to be adequately sensitized on the inherent benefits of the adoption of the tool in Kaduna. This is because its goodwill and support is a pre-requisite to the successful and sustainable utilization of the tool within the framework of the day to day operations of the Authority.

5.40 Conclusion

The examination of the findings of the research along with other general observations supports the advancement of two general conclusions. The first conclusion is that the integrated sprawl analysis tool as conceived in the early and initial stages of the research is workable and viable. Second, that its application in the mapping and analysis of sprawl in Kaduna has demonstrated that urban planners and managers alike can utilize it as a cost effective, convenient and accurate means of monitoring urban growth, analyzing varying resultant patterns and simulating the implications of any such resultant patterns of urban growth and development. This then offers tremendous opportunities for effective monitoring and management of development which currently is lacking in Kaduna and most other urban areas in Nigeria.

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