Spatial Data Infrastructures: African Experiences

Boipuso NKWAE and Dr Sue NICHOLS, Canada

Key words:

ABSTRACT

There is general agreement that spatial data is a key to sustainable resource management and overall economic development of a country. Spatial data infrastructures (SDIs) in turn provide the underlying foundation for accessing and using spatial data in the decision-making processes. In order to provide better awareness of the importance of SDIs especially in Africa, there is need to more clearly articulate what an SDI can do and how it relates to other information initiatives such as GIS and cadastre. The benefits of SDIs should not be tied to only promoting existing programs, but should also include the opportunities and possibilities for truly creating societies in which spatial information is made available efficiently, effectively, and equitably.

This paper will describe the characteristics and concepts of spatial data infrastructures as they have emerged over the last decade. It will also review the developments in SDI that are taking place in selected African countries, and assess the particular African opportunities, challenges and implementation issues. The paper will then argue that even though much of the region may not be prepared for a full SDI implementation, organizational and institutional arrangements should be put in place to ensure full participation when other physical aspects of the infrastructures become available.

CONTACT

Boipuso Nkwae and Dr Sue Nichols
Department of Geodesy & Geomatics Engineering
University of New Brunswick
P.O. Box 4400
Fredericton N.B. E3B 5A3
CANADA
E-mail: boipuso@unb.ca and nichols@unb.ca

Spatial Data Infrastructures: African Experiences

Boipuso NKWAE and Dr Sue NICHOLS, Canada

INTRODUCTION

There are myriad programs and projects aimed at the development and improvement of spatial data in the African continent. Some initiatives aim to create an environment that enables a wide variety of users to easily access and retrieve spatial data sets in a complete, consistent, reliable, and secure manner. Many more are tailored to the specific needs of a ministry or program. The main purpose of this paper is to examine some of these initiatives, in order to help identify particular challenges and opportunities within Africa in developing spatial data infrastructures (SDIs). SDIs are more than just another mapping program or a geographic information system (GIS) or network. They provide the underlying framework of policies, standards, organizations, technologies, and spatial data for information services and products. SDIs also provide the foundation for ensuring that all citizens can actively and effectively participate in an information rich world.

An infrastructure is an enabling mechanism to allow the efficient, effective, and equitable sharing and use of existing data, as well as creation of value-added products and services. The premise of building SDIs is that without an environment in which all spatial data stakeholders (both users and producers) can cooperate and utilize information and technologies in a cost-effective way, objectives such as poverty alleviation, sustainable economic development, environmental planning and protection will be difficult to achieve. The objective of this paper is not to examine this assumption in particular but to review how conditions in Africa offer special challenges and opportunities in SDI development.

This paper will address the following questions in order to provide an overview of SDIs in an African context:

1. What is an SDI - is it just a new term for existing activities?
2. Why is the development of an SDI important in African countries?
3. What are some of the current initiatives towards SDIs in Africa?
4. What are the specific African issues?
5. What should be done to address these issues?

1. SPATIAL DATA INFRASTRUCTURES - WHY AN INFRASTRUCTURE?

1.1 First principles

In 1991, *Scientific American* ran a special issue on the emergence of data infrastructures or what became better known as "information highways." In this issue various authors reviewed not only the technologies that were creating a new environment for work, for recreation, for learning etc., but also the reason why data infrastructures are different than databases, the internet, and the various conglomerations of communication networks, hardware and software that were emerging. It is from this broad perspective that we would like to view

SDIs. Technologies and opportunities have changed considerably since even 1991, but the basic concepts behind developing of data infrastructures still remain.

This distinction is important because much of the current literature and thinking on SDIs in the world of geomatics has tended to focus on an SDI as either a set of digital databases (e.g., cadastral, topographic) or as a super-network of GIS and web-based technologies focused on improving data sharing and data access. The term SDI is often therefore used to describe what various jurisdictions have already done (with some enhancements) or what they may have planned. We would like to challenge this notion by going back to the vision of an "information infrastructure" as a broader enabling platform for future applications and developments [e.g., McLaughlin, US Academy of Science, McLaughlin et al., 1993]. After all, why invent the term *infrastructure* when *network, data warehouse, appliances, GIS, land information system (LIS),* etc., or a combination of these, may be sufficient to describe current ventures. We propose that the term infrastructure implies much more than data collecting, conversion, and management. What an infrastructure truly creates is the institutional, policy and organizational framework for using technologies and data more effectively.

The early analogy to a "highway infrastructure" or a "power infrastructure" may be simplistic but it serves to highlight some important characteristics of an infrastructure and why SDIs are in their infancy. In fact these characteristics are what makes SDIs critical elements for economic development, environmental protection, and good governance. Among the important characteristics that distinguish an SDI from projects, technologies, or applications are [after Dertouzos, 1991]:

An infrastructure must be widely available. It is a national or even global strategy, not designed to serve the interests of one group of users (e.g., a single Ministry, level of government, or profession) but to serve society at large. Publicly accessible datasets and networks, with maximum user capacity, are essential if, for example, all citizens – from schoolchildren to financial advisors and politicians – are to participate effectively in an information society.

An infrastructure must be easy to use. Weiser [1991] notes that *"the most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it."* Accessing an SDI must become as easy as turning on the lights in your home thereby tapping the powerful electrical infrastructure that spans jurisdictional and organizational boundaries. New technological capabilities just beginning to emerge in every country (e.g., cell phones, web browsers, and internet cafes) are an integral part of making data infrastructures a part of everyday life for an increasing number of people. Even complex spatial models must become as easy to access and use as e-mail text and chat rooms.

An infrastructure must be flexible. The infrastructure must be independent of specific technologies, types of data and database structures, and specific organizational arrangements. Standards and protocols must allow for a wide variety of technology configurations and the

infrastructure must be built to meet unimagined as well as existing needs and organizational structures, i.e., there must be an innate capacity to anticipate and manage growth.

An infrastructure must be multipurpose. It should not be confined to the concerns and datasets of a particular program, department, or system. In terms of spatial data, the infrastructure must facilitate the use and sharing of data beyond departmental or even sector mandates. It is neither program nor agency dependent; SDIs should facilitate horizontal as well as vertical flow and integration of spatial data. Thus, for example, a cadastre or an information service adds components to an infrastructure, but they alone are not the SDI.

An infrastructure is the foundation for other activities. An SDI is not an end but a means. It facilitates the use of spatial information in a variety of applications and must be able to respond to new opportunities and new user communities. The purpose of the infrastructure is to foster and not to control new applications, services, and industries so that the full potential value of spatial information can be realized.

Therefore an SDI is much more than a national mapping program, or an organization providing a spatial data portal. If we are to capture the imaginations of politicians and technocrats and if we are to understand our own programs and projects within an SDI context, then we need to see the SDI as a platform, a springboard, an approach or strategy. It is there to provide the basis for applications and ideas we do not yet possess or dream of, not simply to repackage the tools, techniques, and datasets we currently have or are trying to develop.

1.2 More Recent Developments in the SDI Concept

1.2.1 Objectives of an SDI: The goal of a spatial data infrastructure is to ensure that users will be able to acquire and use adequate, complete, reliable, and consistent data sets when they need them. One objective of an SDI, therefore, is to provide an ideal environment in which all stakeholders (both users and producers of spatial information) can cooperate with each other cost-effectively to better achieve their targets [Rajabifard et al., 2000]. Authors recognize that SDIs facilitate better management and utilization of spatial data assets. Masser [1998], for example, summarized the objectives of an SDI as the promotion of economic development, the stimulation of better government and the fostering of environmental sustainability. All the above stated objectives are very relevant to the African situation that is still very poor even though it is very rich in terms of natural resources.

1.2.2 A Hierarchial Model: Rajabifard et al. [2000], propose that a national SDI is made up of inter-connected SDIs at corporate, local, state/provincial or national levels. In their model, a corporate GIS could be seen as an SDI at the corporate level, the base of the hierarchy. Going up the hierarchy, Land Victoria in the State of Victoria (Australia) provides major components of emerging provincial/state level SDIs. They further argue that each SDI at the local level or above is primarily formed by integration of spatial datasets originally developed for use in corporations operating at that level or below. In applying the hierarchy relationship model to SDI concept they use the part-whole property of a hierarchy structure which states that an element on a higher level, like a state/provincial level, consists of one or more

elements on the lower level, such as different local SDIs. According to Rajabifard's et al [2000] argument, it follows that a corporate or advanced GIS network, a cadastral system, a land information system or an environmental information system if it has the basic components of an SDI qualifies as a subset of a SDI. This hierarchical model reflects the way in which surveyors and mappers have traditionally viewed data integration and flow.

2.1.3 An umbrella model: A similar way of looking at SDIs is by using the umbrella view of a national SDI as encompassing all basic components of those at the lower levels (Rajabifard *et al.*; 2000). This view is consistent with the long-term development of the national SDI concept. However, this view has to be modified to avoid possible duplication of efforts, and to ensure co-ordination of SDI development at all levels. This national umbrella model might imply that each government department or region should establish its own SDI. However, these tasks should be overseen by a national SDI steering committee. Multinational and global efforts add a further co-ordination layer. This hierarchical model emphasizes data sharing/trading, cross-referencing and partnerships and reduces the overall cost of data collection. This can be represented graphically by forming a pyramid of building blocks, from a local level to a national level.

2.1.4 An institutionally-grounded infrastructure model: Coleman and McLaughlin [1998] identified policies, organizations, technologies, standards, human resources, and datasets as the basic components of a SDI (See for example, Figure 1 [after McLaughlin and Nichols, 1994]). The GIS as described in the hierarchical model is thus only one part of an SDI, otherwise why not call it a "national GIS" or "national land information system"? The emphasis here is on building the institutional and organizational framework to allow whatever technologies, datasets, and applications to be integrated (or segregated) horizontally and vertically in any environment (e.g., school, municipality, eastern region of the country, continental). This model challenges SDI creators to think beyond the current limits of our understanding of GIS, web technologies, and even provincial or national land information systems (see also 1.3 below). The emphasis is on future "infrastructure" rather than products and services already in place. The emphasis is also on a achieving co-ordination beyond the local or mandate specific level.

1.3 Related Concepts

Are geographic information systems a type of a SDI? The answer is yes and no – "No" in the sense that GIS can be defined as the software packages and computer hardware that

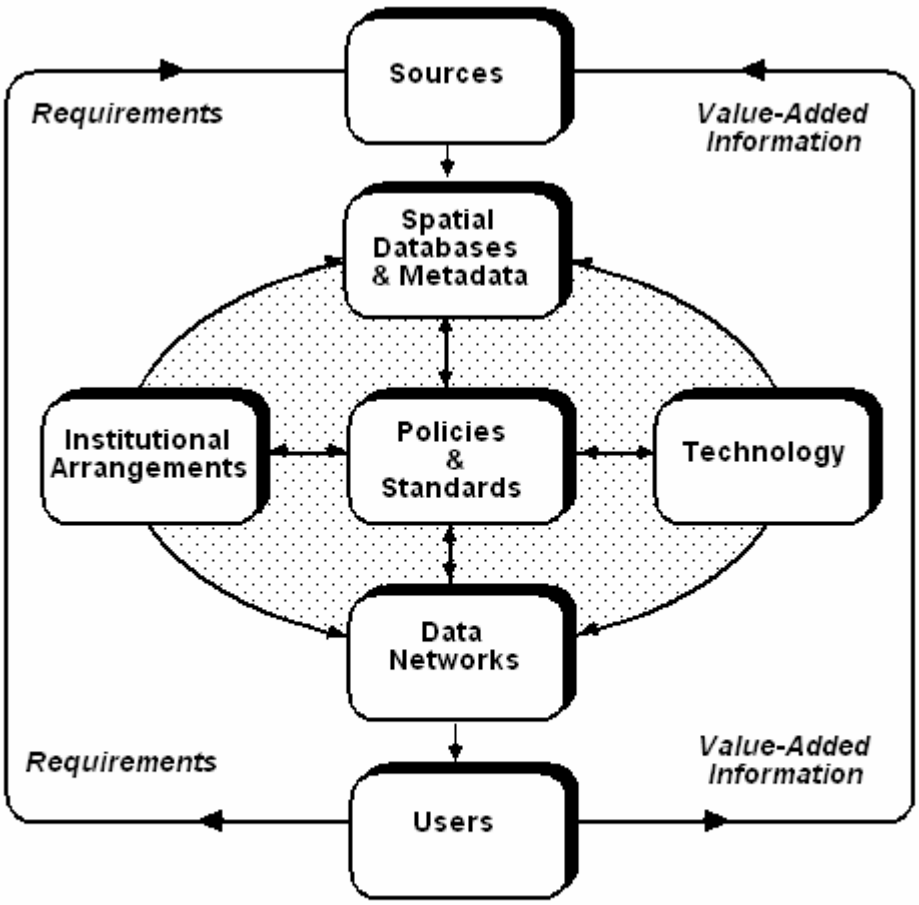

FIGURE 1: NSDI Components - A Systems Perspective

integrate spatial data and non-attribute data to produce the spatial information for decision-making. Here GIS is a **tool**. It is a set of procedures and techniques for analyzing and manipulating spatial data. The second meaning of GIS involves the creation, maintenance and continuous updating of a database. The resulting database created, maintained, updated, manipulated, analyzed by the GIS tool is also referred to as a GIS. Here the GIS is used as a **resource,** no different from any other type of information system but still does not qualify to be described as an "infrastructure" per se.

On the other hand, when the maintenance of this resource involves the organization, the cooperation, and the coordination of information from several government departments, private sector, research institutes, non-governmental organizations, community-based organizations, donor and multi-lateral agencies, then the answer is possibly “Yes - it can form at least a major part of an infrastructure”. In this case GIS requires not only standards for operation of hardware and software and knowledge of spatial analytic techniques but also legislation and policies, coordinating arrangements, common standards, common geodetic references, common base data to enable data to be accessed, traded or shared. Different users and/or suppliers would be assigned data custodian responsibilities for the subsets of data.

With these arrangements in place, the users can now expect the spatial data to be available, accessible, complete, up-to-date, consistent and secure. At this stage, the GIS can be described as a significant building block of an overall national or state **infrastructure**.

Others have argued that a cadastre is a basic building block of the SDI. Many economic, regulatory, and subsistence activities on land are organized around a land parcel. A cadastral system stores information about ownership rights, parcel extents or boundary information, land use, land value, and may provide an information component of land registration and land taxation. Over centuries cadastral reforms have been undertaken in response to the ever-changing needs of society. One of such reforms was the introduction of the multi-purpose cadastre concept which encompasses both the fiscal and the juridical cadastres with the addition of other parcel-related information with the focus on providing integrated data at the local level [e.g., McLaughlin et al., 1977]. The cadastre, however, by its emphasis on parcel-based data, can only be part of the total SDI.

Also, in most African countries, cadastral information is mainly limited to urban jurisdictions. This is partly a legacy of colonialism whereby only a tiny segment of the population was allowed access to cadastral records. For example, only 1.2% of the population in Zimbabwe was allowed access to cadastral information before independence in 1980 (Chimhamhiwa and Lemmen, 2001). Cadastral systems in their present form are not usually as relevant to rural Africa as they are biased towards functioning land markets and land taxation. In rural Africa, there are very few land transactions to justify the costs of setting up a very expensive cadastral system [e.g., Fourie and Nino-Fluck, 1999].

2. THE BENEFITS OF NATIONAL SDIS IN AFRICA

Governments around the world are beginning to realize that geographic information is one of the most critical elements underpinning analysis and decision making for environmental, economic and social development. Much of this development is concerned with how people interact with land and space. Without knowledge of spatial relationships among, for example, demography, natural resources, and socio-economic constraints, those responsible for land policies are limited to addressing issues in isolation. Information collection and management programs have been costly and have had limited success (as for example, measured in terms of completeness, maintenance, and integration), especially in developing countries. Governments are therefore searching for better ways to allocate resources in the spatial information sector. New technologies hold out some promise but the human resource and organizational issues are still largely unresolved.

One solution has been to emphasize the development of data infrastructures that can allow other information activities to evolve over time in a more cost-effective and cost-efficient manner. Many countries in Africa are just now beginning to explore this idea. Some of the benefits that an SDI can offer in African countries are:

- Enhancing the sharing and open access to data/information by different users for a variety of environmental, natural resource management and development planning applications.

- Enhancing the scope for efficient use of human and natural resources in a country while making the distribution of data and social dimensions associated with data access more transparent.
- Increasing knowledge about African natural resources thereby increasing the chances of investment.
- Increasing the general level of knowledge and access to information within the African society (e.g., in schools, in communities, and organizations) and thereby stimulate economic growth and more democratic participation in national and local processes.
- With SDI in place, new poverty alleviation programs can more efficiently target problem areas and solutions using geographic information and analysis tools without having to begin the programs with extensive data collection schemes.
- SDIs can help provide the foundation for badly needed monitoring programs (for environmental, economic, and social changes) in a more cost-effective and consistent manner.

3. SDI ACTIVITIES IN AFRICA

Many countries in Africa such as South Africa, Botswana, Zimbabwe, Namibia, Zambia, Uganda, Morocco and Tunisia are on their way to developing spatial data infrastructures (SDI) to better manage and utilize their spatial data assets. A number of publications document the various aspects of the development of national SDIs in recent years [Onsrud 1998; Bassole 2000; Ezigbalike 2000; 2001]. In several of these countries, initiatives to develop SDIs are already underway notwithstanding the terminology used in different countries to describe them.

Current progress in national SDI initiatives in Africa shows that after many years of effort these initiatives still do not receive support from the highest level of government because of the low level of awareness of the importance of spatial data and information in decision-making [Ezigbalike 2001]. This means that, despite all the interest and activities, SDI development in Africa and other developing countries remains very much an innovative concept among different user communities. This problem can be observed in specific SDI initiatives in African countries. Some reasons suggested for the limited support from most African national governments and other relevant institutions are:

- Lack of awareness of the value of SDI
- Confusion surrounding the definition or composition of SDIs
- Lack of policy and coordinating arrangements
- Complexity of national issues such as the political, cultural and economic positions of most countries

Ezigbalike [2001] recommends the following short-term activities required to prepare Africa for national SDI development:

- Introduce the concept of information budgeting
- Identify a lead agency or person to coordinate the development of SDI including the establishment of formal coordinating mechanisms

- Use workshops and seminars to increase the level of awareness of SDI
- Perform national reviews of spatial data needs and available data
- Develop online learning materials on SDI

Based on the approach, it appears most of the basic challenges faced by African SDI initiatives in its future development and implementation can be minimized.

In addressing the problems faced by SDI initiatives in Africa, one of the solution lies in increasing the level of understanding and awareness of people (both users and producers of spatial data, and concerns of relevant politicians) about the nature and value of SDI concepts in general and the differences between related concepts such as cadastres, geographic/land information systems.

3.1 National SDI Initiatives:

In Botswana, the Department of Surveys and Mapping (DSM) has several on-going projects as part of the process of implementing the national information infrastructure program. For instance, the digital atlas will be completed in March 2002 as part of the national SDI development process. The Government Computer Bureau (GCB) is involved in the creation of a Master Plan for the implementation of the country's GIS strategy which will be further developed to lay the foundation for the national geospatial data infrastructure. Other SDI related developments carried out by DSM include capacity building in data capture (e.g., measurements for zero-order network, database management, etc.), the creation of the new digital national cadastral and topographic databases, and the design of a web solution for seamless orthophoto coverage of the entire country. The Department of Town and Regional Planning (DTRP) has digital databases to support, among other functions, land use compliance monitoring in urban areas. The District Land Boards maintain computerized land inventories, and the Department of Lands maintains a textual database of all allocated plots in all urban areas.

In Lesotho, the Mapping Agency has introduced the production of large-scale (1:2,500) digital mapping for urban areas, as well as the project to digitize the 1: 50,000 map series (Ezigbalike et al. 2000). In terms of coordinating arrangements, Lesotho has established some sort of a dedicated inter-sectoral coordinating body, the Committee on Environmental Data Management (CEDAMA). The terms of reference of CEDAMA include (Ezigbalike et al. 2000):

- To promote a culture of environmental data exchange;
- To advise National Environmental Secretariat (NES) on issues of environmental database management;
- To establish data quality standards;
- To advise NES on the formulation of relevant policies on management data;
- To advise NES on measurable environmental quality indicators for different sectors of the economy;
- To assist with the analysis of trends in the environmental quality indicators, and recommend mitigation measures.

3.2 Regional SDI Initiatives

Despite the many existing constraints, there is a lot of SDI building activities in Africa. In Zimbabwe, the Southern African Development Community Food Security Programme (SADC-FSP) based at the Regional Remote Sensing Unit (RRSU) has since 1994 been developing spatial databases to support the analysis of remote sensing products. The databases include a wide range of information on national and sub-national boundaries, elevation data, infrastructure, hydrology, major growing areas, forests, protected areas, cultural sites, climate and agricultural data. Although the main focus of the RRSU is on early warning for food security, it has also became clear that its activities and databases are beneficial for a wide range of environmental applications and spatial data activities (Viergever 2001).

On a continent wide scale, a program for environmental information systems in sub-Saharan Africa (EIS-SSA) has since the early 1990s been established. Bassole (2000) reports that these resulted from a "continent wide series of National Environmental Action Plans (NEAPs)" which started in the late 1980s to early 1990s in response to the challenges of striking a balance between economic development and sustainable resources management. Although the original context of EIS was biased towards the technology, early experiences in implementing them brought out the need for "establishing an appropriate institutional framework to facilitate the generation of environmental data sets" [Bassole 2000].

> Even though EIS-Africa seems to be more environmentally focused than geo-spatial data oriented it actually is a continent wide effort focused on developing an SDI for Africa [Bassole 2000, p.116].

This involved the standardization and harmonization of available data sets, promotion of the concept shared data resources at the national level, development of capacity to use them in environmental decision-making, as well as development of partnerships with organizations with similar objectives. Perhaps another approach that the EIS Program should have followed would have been to understand the requirements, the constraints, and the opportunities in an African context and then build the principles for a spatial data infrastructure initiative for Africa. It seems the EIS Program has taken the approach that suggests that SDI is "the magic bullet of the decade and Africa had better get with it and adopt (not adapt) what the rest of the world is doing".

4. MAJOR CONSTRAINTS IN SDI DEVELOPMENT IN AFRICA

4.1 Low awareness of the role of information in decision-making

Generally, computer literacy is very low in Africa, and the value of electronic communication and the World Wide Web are just beginning to be appreciated. Other applications such as e-commerce and document transfer protocols are still regarded with awe. With regard to the use of the Internet, the BBC [2002] reported:

> It is not terribly high on the government's agendas and many are not bold enough to allow people to access more information because it is empowering and [African] governments are wary of that.

They further stated that the average cost of dial-up access in Africa is about 40 pounds sterling per month – expensive even by Western standards.

4.2 Coordinating arrangements

There is need for an institutional framework that can coordinate the different activities and implement the policy in the field of spatial data. This coordinating work has in the past been undertaken by National Mapping Authorities but their role has been challenged for several years in both developed and developing countries [Norplan As, 2001]. Institutional issues can be the most difficult to address but organizational arrangements are the pre-requisites for establishing a national SDI and it might involve data producers and the users, NGOs, CBOs, multi-lateral and donor agencies, the government, the academic sector and research institutes as well as the private sector.

The current trend throughout the world is the creation of new alliances to promote the use, distribution and sale of geographic data. In South Africa, for example, the National Spatial Information Framework (NSIF), although still in its infancy, has been established as an umbrella organization to handle search, query, find, access and use of geographic data. Other examples outside Africa include Canada's Geo-Connections, USA's Federal Government Data Committee (FGDC), UK's National Spatial Data Framework (NSDF), and the Australian Spatial Data Infrastructure (ASDI). On the regional scale there is the European Geographic Information Infrastructure (EGII), and the similar steps are being taken in the Asian region. There is no umbrella organization today responsible for supporting such regional or global initiatives in Africa.

4.3 Financial constraints

Africa has one has lowest GNP ($520 compared to $23,090 of developed countries) in the world with many of its people surviving on less than US$1 a day (Botswana Government: National Development Plan 8, 1997). Because of limited financial resources funding in the area of Internet technology has mainly come from external agencies such as USAID, Canadian CIDA, and the British Council. The cost of buying a mobile phone (about $200) that combines data, voice and Internet capability will be beyond the reach of majority of the African people. Computer technologies and associated telecommunications software have to be bought with hard currencies like the US dollar or pound sterling, and foreign exchange is in short supply in Africa (balance of payment problems). In addition, there are considerable costs involved in training users as well as technicians to ensure that the network is reliable and easy to use.

SDI projects/programs in Africa are therefore heavily dependent on donor funding. The major problems with this include: a) short term funding does not always match long term program development (e.g., development of policies and laws and interagency standards); b)

SDI components can lapse after funding is completed unless capacity development is emphasized; c) donors often specify the approaches that should be taken and these may not always meet local needs and constraints. One example of the latter has been the emphasis in the last decade on making projects self-financing and cost-recoverable. Such policies can often create an informal information market to avoid the formal fees and charges.

The Norplan As (2001) study on the economics of environmental information systems in Africa also found that:

1) The current market for geo-referenced data/information is limited in sub-Saharan Africa, that is, the willingness and the ability to pay is relatively low. This is not surprising since most of the population survives on less than one US dollar a day and paying for spatial data will not be a priority for most communities.
2) In addition, the distribution of data to the users is one of the main bottlenecks related spatial data — there is no main distributor of geo-data in different countries.
3) The administrative, legal and institutional issues need to be addressed, an example of which is when organizations are forbidden by law to sell their data.
4) Even in cases where data is sold, there is no free disposal of income from selling data. Usually the money goes to central pool (government revenue office) and allocated to other government projects. A major part of the revenue should be ploughed back to the producers of spatial data.
5) Lack of demand of the product which is also linked to the lack of ability to pay. The product might be needed but lack of willingness or ability to pay results in lack of demand.

The above findings also apply to SDI as environmental information system is a subset of a national SDI.

4.4 Private Sector

The absence or the insignificance of the private sector in the production of geo-data is exacerbating the already worse situation, and Norplan AS (2001) attributes this to the absence of a well-functioning market place for geographic information. They further state that the private sector is engaged in data collection when there is:

- An absence of adequate data sets;
- Poor quality of existing data;
- Lack of reliability of existing data; and
- Governmental production of geo-data takes too long.

Whereas the private sector can be motivated in western countries to contribute to an SDI as well as make effective (and financially sustainable) use of an SDI through value-added products and services, such opportunities are as yet more limited in Africa. Data pricing policies emphasizing cost-recovery by government can further limit the private sector participation. Even in Canada and Australia, cost-recovery policies are increasingly viewed as a barrier to development of SDIs and vibrant information markets.

4.5 Inadequate personnel

Information, communications and knowledge technologies are high technologies and require skilled and experienced personnel to maintain and use them. The skills needed range from data capture, data processing and analysis, to data/information dissemination. Professionals in the various fields such as geodesy, surveying, photogrammetry, remote sensing, computer graphics and database design, planning, land management, land administration, environmental management, forestry and agriculture are thinly spread across the continent. As Ezigbalike et al.[2000] reported:

> While professionals with these specializations may be available in some departments they are thinly spread and there are still few with enough cross-disciplinary mix required for the maintenance and application of spatial data infrastructures.

Another aspect of the personnel problem is the rampant brain-drain which is prevalent in Africa and other developing countries.

> South Africa loses 15 – 20% of its skilled technical workers each year. By one estimate, more than half of college students from developing countries who study abroad never return. [The Economist, 2001]

Low salaries in Africa and the poor working conditions contribute to the low morale among workers. There is no incentive for professionals to engage in self-improvement courses and the little time they have is spent moonlighting in order to make ends meet. Most governments in the region neglect the fact that:

> Scientists must eat. They also need money for computers, test tubes and bits of pig to experiment on. Developing countries have two difficulties in funding their own R & D. One obviously is lack of money. The other is that even if they have spare cash, they do not usually have flexible and efficient mechanisms for directing it to useful research. [The Economist, 2001]

African countries should try and create an environment where scientists and other professionals can find a challenging and adequately rewarding jobs at home.

4.6 Legacy data

Existing topographic map coverage in Africa was produced using aerial photogrammetic methods between the 1950s and early 1970s by colonial governments and is substantially out of date. Much of the spatial data about Africa is held by outside organizations and governments such as the CIA of the United States of America, the then Department of Overseas Surveys of the United Kingdom and France. Most of this data/information is however still in paper format and arrangements should be made to make this information/data easily accessible to a wider range of users by incorporating it into an SDI.

4.7 Spatial data standards

Standards are required to facilitate the exchange of data across government departments, non-governmental organizations and the private sector. Spatial and non-spatial data standards are needed. Some of these standards have already been developed in the West by the International Standards Organization, Technical Committee 211 (ISO-TC 211).

> The reality in most African countries is that these issues [spatial data standards] have not yet been formally addressed. Where they have been addressed, they are not usually adhered to. The value of information has not yet been realized, and it will not be if policies and standards are not in place. [Ezigbalike *et al.*, 2000]

To avoid reinventing the wheel, African countries should keep themselves informed of international developments and adapt these international standards to meet their specific requirements and constraints.

4. 8 Foundation or base data

The situation in Africa is not directly comparable with other countries in the world. There is a serious lack of geo-data, uncoordinated data collection activities, and non-homogenous market/user groups with low level of competence and lack institutional frameworks to play a leading role in SDI development.

4.9 Utility infrastructures

The most effective data channels of the 21st century so far are computer networks and the Internet. These are unfortunately under-developed within Africa. The information infrastructure depends on other utility infrastructures such as electricity and telecommunications. In most countries, electricity is only available in towns and major villages, leaving the rest of the country without power. These rural areas are in most cases the subjects of data, e.g. environmental and natural resources data. Access to information should therefore be provided in rural centres.

In some countries, even if power is available, the supply of electricity is not constant and there are frequent power outages and surges that may result in damage to sensitive computer equipment. Even if computers can be bought, their cost in this regard is pushed up because it has to include power backup such as the supply of a stand-by generator.

5. DEALING WITH THE CONSTRAINTS

5.1 Finance

Multi-lateral and donor agencies have a tendency of funding single projects in African as well as in other developing countries, and this has the effect of increasing diversity instead of strengthening the national spatial data infrastructure initiatives. There is a lot of competition

among donor agencies and this calls for cooperation and coordination of donor funded projects and programs in order to increase the impact of aid in these countries. Because donors do not talk to each other there is a tendency to fund similar projects which results in sub-optimal national projects.

There is a need for countries to take more responsibility in co-ordinating the aid in spatial data programs and ensuring that maximum benefits can be reaped. This co-ordination must include setting national priorities. Development of policies, laws and standards to encourage, rather than discourage, the use of data and information technologies will also contribute to the sustainability of major investments in data collection and management.

5.2 Awareness Building

Greater awareness of SDI among users, producers, decision-makers and politicians will result in their growing support for SDI implementation. In most African countries, planners, land administrators, land surveyors and environmental managers are aware that something must be done to improve the geo-spatial information base in support for their functions. This can be achieved by using strategies including:

- Introducing training courses on the use of spatial data for decision-making.
- Arranging workshops, seminars and conferences on SDI development with emphasis on the use of geo-spatial information for professionals, decision-makers and politicians.
- Exposing African experts to geo-spatial information management technologies and their implementation during visits and training sessions in developed countries.
- Developing a national vision of what an SDI can contribute to the country in order to communicate ideas to senior management and political levels.

5.3 Capacity Building and Skills Sharing

Capacity building is needed across the continent to overcome the personnel and the awareness problems. Specific recommendations to provide education and training in information, communications and knowledge (ICK) technologies to alleviate the shortage of skilled and experienced personnel include the following:

- Study visits to developed and other developing countries could play a major role in terms of skills sharing.
- Develop web-based self-learning material on spatial data utilization and SDI advantages [Ezigbalike 2001].
- Conduct a series of workshops and seminars to explain and publicize the SDI concepts
- Development of regional centers of the UN Economic Commission for Africa (RECTAS, Ile-Ife; RCMRD, Nairobi); SADC-FSP, Harare; AOCRS, Algiers; and other similar organizations to coordinate and mediate the sharing of expertise between countries;
- Funding of research within African universities to examine and develop SDI concepts and applications.

5.4 Re-engineering the Spatial Data Industry

Spatial data has been collected for various reasons ranging from land administration to military applications. This role of data collection has been the responsibility of national mapping organizations (NMOs). Recently, their role of information management has expanded considerably. National mapping organizations are still playing a very important role, but rapid changes in technology development and in the expectations of the consumers (users) has led to a total restructuring of these organizations.

The developments in information technology, especially GIS, have changed the focus from map production to databases, and Internet has developed as the new distribution channel for spatial data.

The current trend in countries with a long history of mapping and surveying is partnerships between the public and private sectors are now developing. The role of mapping organizations will change from producer and distributor of map data to a coordinating role without being involved in production. However, most African countries have national mapping organizations, but due to inadequate resources, they have not fulfilled their role. Other institutions involved geo-data production have challenged their traditional role. With donor support some NMOs have produced vast amounts digital data and because of the prevailing culture, the data has not been regarded as a national resource but as property of that institution. This is also true for other government departments that produce geographic data. African NMOs, like in developed countries, should play a more central role in Africa and provide all users and institutions with foundation data. NMOs in Africa should follow the trends in the rest of the world and move from data ownership to data custodianship. In this case, government departments are assigned custodianship responsibilities to contribute and maintain specific datasets for the community of users and there should be privileges/incentives going with such responsibilities.

5.5 Cost management rather than cost recovery

Cost recovery prices are expected to cover such costs as data collection, storage, maintenance and distribution. The price could also be determined by quality of data e.g. the level of details, correctness, up-datedness, completeness, topological continuity and usage. In the case of usage, some countries may charge lower fees for the government, non-governmental organizations and academic institutions and set higher fees for the private sector.

Correct pricing is difficult to achieve. If prices are set too users will probably produce their own data; if prices are too low there are no funds to keep data up-to-date. There are various models of cost recovery ranging from full cost recovery to no cost recovery. Countries that have tried cost recovery like Canada have admitted that cost recovery in spatial data infrastructure was a mistake. The issue of cost-recovery should be addressed in an African context and not in terms of European-American context where the information and knowledge society is more “mature” as this tends to distort the “development” of an infrastructure in a developing country. ***However, in the African context, there should be no***

cost recovery for the foundation data sets, and data should be made available to everybody at the price of maintenance.

Current thinking today is that there is little point in cost recovery of 100% for public data [Norplan AS 2001]. For instance, there are cases whereby data might be required for monitoring natural disasters (environmental data) or national security reasons and even though this data is very important it might be of very little commercial interest. Despite the low commercial demand, those who benefit most from such data should pay and ease the burden of taxpayers.

5.6 Utility infrastructures

Developing nations in Africa, Asia and Latin America are keen on participating in the global spatial data infrastructure initiatives. But to enter into this digital world, they are going to need telecommunications networks to carry data and voice. But telecommunications infrastructure is poorly developed in Africa. As Overton [1999] points out, "in Africa there are just over 14 million copper phone lines serving a population of 800 million. By contrast, the United States has 169 million lines". This explains why the majority of its citizens still do not have access to telephones, and the long waiting lists. Telecommunications companies, which are still government monopolies, are still struggling to provide voice lines to more people. The provision of data-enabled high bandwidth lines is therefore not yet a priority.

However there is hope for Africa in this regard, by leapfrogging traditional copper-and-fibre-based landlines and going directly to wireless. This view is shared by Overton [1999] when saying:

> So while the West struggles to integrate aging legacy telecom infrastructure with new investments, in satellite and cellular, developing countries are going right to leading-edge wireless technologies that blend voice and data over the same networks.

The fact that the African countries have nothing in terms of information infrastructure may be viewed as an advantage in that they are going to start from a clean slate. At the moment, the advent of wireless technologies can be described simply as a "gold rush" as major telecommunications companies are busy building big network projects in many developing parts of the world. As reported by Overton [1999], Siemens won DM260 million in contracts to build four mobile communications networks in China. At the same time, Lucent Technologies announced a major deal in Peru to offer a high-speed wireless Internet and multimedia services in Lima. Africa has not been left behind either. Wireless networks are being built in Ethiopia, Uganda and West Africa. The Birmingham Post [2000] when reporting about Satellite Media Services stated:

> While Europe is well served for Internet facilities with a backbone of fibre cabling under the Atlantic, and widespread underground networks across the UK and the Continent, emerging countries (in Africa)…have little in the way of IT infrastructure. Many also have geographical problems such

as distance, inhospitable climates and physical difficulties, leaving satellites —or fibre in the sky their best solution for linking up to the Internet.

6. SDI DEVELOPMENT PROCESS IN AN AFRICAN CONTEXT

For any SDI initiative to succeed in Africa, the development process should be home grown and be based on national realities and capabilities. The development of any SDI initiative should follow at least four phases:

1) The Awareness Building Phase
This phase should involve the creation of awareness of the use and advantages of having an SDI, that is, it should emphasize the strategic importance of SDI in economic and environmental management.

2) The Development Phase
This phase is characterized by the development of coordinating arrangements, strengthening of institutions, human resource development and production of foundation data sets.

3) The Post-Development Phase
The post development phase would involve building on the achievements of the development phase.

4) The Implementation of a Nationwide SDI Strategy
This final phase assumes that all the infrastructure and associated technologies and metadata standards are in place for a fully-fledged online SDI implementation. For most African countries the dream for a fully-fledged online SDI will remain a dream for a foreseeable future.

7. KEY SUCCESS FACTORS FOR SDI DEVELOPMENT IN AFRICA

The key success factors of a national SDI in Africa are the following:

- The spirit of cooperation among the agencies involved in SDI development is critical.
- The presence of a reliable and trusted coordinator and driving force ("the champion factor") in the SDI development effort.
- The establishment of a functioning and effective network among the SDI stakeholders.
- The availability of base or foundation data and skilled and experienced personnel.
- The support of the donor community is critical.
- The identification of SDI development as a national priority issue.
- The support of politicians, decision-makers and senior management of agencies involved in national SDI development.

What are the priorities for SDI in an African context? There is need to understand what the requirements are for the development of SDI in an African context. If we know what the constraints are and what the opportunities are for SDI development, we will then be in a better position to build the principles for a spatial information infrastructure program for Africa. However, we should remember that SDI is not a panacea for all the economic and

political ills that have befallen Africa and that most approaches that have been taken with regard to the development of SDI have tended to emphasize the point that "Africa had better get with it and adopt (not adapt) what the rest of the world is doing".

As Dertouzos [1991] defined the problem:

> *...we, the designers and users of this information infrastructure, bear a serious responsibility: we must understand the value and role of information so that we may better channel our technological miracles into useful rather than frivolous, if not dangerous, directions.*

8. CONCLUSION

This paper has reviewed the African experience of spatial data infrastructures. It has also clarified the confusion regarding the relationships among related concepts such as GIS, LIS, cadastres and SDI. One of the major challenges for most African countries is to build a sustainable spatial data infrastructure within a reasonable time frame, but also one that can accommodate future needs and opportunities. The procedure that should be taken in the African context should not be a 'big bang' approach and the following is suggested:

- Successful introduction of SDI is to "think big, but start small",
- Planning should adopt a widest perspective in the conceptualization of SDI,
- Development should be incremental and in small separate stages,
- A team/committee should be constituted in country with detailed knowledge of strategic planning process and the issues involved in SDI development and implementation.

The benefits of the above approach are that it shortens the lead-time on implementation that results in a quicker return on financial investment. This would enable the development of a technological bank in the form of experienced personnel hence solving the problem of lack of skilled personnel (capacity building). Yet, there is also a need for a vision beyond our current understanding of GIS, web-based technologies, and land information systems and our current applications. Africa needs champions to make this work, people who can articulate a clear vision of the future, understand the opportunities as well as the constraints, and muster the available resources to making things happen.

REFERENCES

Bassole, A. [2000]. EIS-Africa: A Network for the Co-operative Management of Environmental Information in Africa, EIS-Africa: 24.

Birmingham Post. (2000). Interactive: Around the world in a millisecond. Accessed from the World Wide Web on 1st March, 2000. http://cnniw.newsreal.com)

Botswana Government [1997]. National Development Plan 8, Government Printer, Gaborone, Botswana.

Coleman, D. J. and J.D. McLaughlin [1998]. Defining Global Geospatial Data Infrastructure (GSDI): Components, Stakeholders and Interfaces, Geomatica, Canadian Institute of Geomatics, 52(2): 129-144.

Chimhamhiwa, D.A. and C. Lemmen [2001]. A Case Study of the Process of Parcel Subdivision in Zimbabwe: Performane Analysis of Cadastral Processes. GIM International (May 2001). 15(5): 68 – 71.

Dertouzos, M.L. [1991]. "Communications, computers, and networks." Scientific American, 265(3), pp. 62-69.

Ezigbalike, C., A. Agumya and U. Okafor [1996]. Enhancing the Utility of GIS in Africa. FIG Commission 3 Workshop on GIS for Sustainable Development/GIS for the Future, Copenhagen, Denmark.

Ezigbalike, C. et al. [2000]. Spatial Data Infrastructures: Is Africa Ready? 4th Spatial Data Infrastructure Conference, Cape Town, South Africa.

Ezigbalike, C. [2000]. The Future Orientation of Geoinformation Activities in Africa. (Accessed from World Wide Web on 12th February 2002. www.uneca.org/eca_resources/Conference_Reports_and_Other_Documents/ disd/codi/docs/FutureGIAfrica_Reviewed.doc)

Fourie, C. and O. Nino-Fluck [1999]. Cadastre and Land Information Systems for Decision-Making in Developing Countries. International Conference on Land Tenure and Cadastral Infrastructure for Sustainable Development, Melbourne, Australia, FIG.

Onsrud, H. [1998]. Survey of National and Regional Data Infrastructure Activities around the Globe. Selected Conference Papers of the Third Global Spatial Data Infrastructure Conference, (Canberra: ANZLIG), 159p.

Overton [1999] Birmingham Post. (2000). Interactive: Around the world in a millisecond. (Accessed from World Wide Web on 1st March, 2000. http://cnniw.newsreal.com)

Mapping Sciences Committee (MPC), N.R.C. [1993]. Toward a Corodinated Spatial Data Infrastructure for the Nation. Washington: National Academy Press.

Masser, I. [1998]. Governments and Geographic Information, Taylor & Francis, London.

Rajabifard, A. et al. [1999]. The Nature of Regional Spatial Data Infrastructures. AURISA 99 – The 27th Annual Conference of AURISA Fairmont Resort, Blue Mountains NSW.

McLaughlin, John. [1991]. "National Spatial Data Infrastructures: The Next LIM Challenge." in Ewan Masters and John Pollard (Eds.) Land Information Management. . Sydney: University of New South Wales, School of Surveying Monograph 14. 1991.

McLaughlin, J. [1997]. "Trends in Canadian Geomatics: From SDI to Community-Based Information Infrastructures", National Academy of Public Administration, Washington, D.C., March 19, 1997.

McLaughlin, John and James Clapp [1977]. "Toward the Development of Multipurpose Cadastres," Journal of the Surveying and Mapping Division, ASCE, Vol. 103, September, pp. 53-73.

McLaughlin, John and David Coleman [1990]. "Land Information Management into the 1990s," World Cartography, Vol. XX, pp. 136-148; Proceedings of the United Nations Seminar on Land Information Management in the Developing World Adelaide, S.A., 1990; pp. 81-104

McLaughlin, J. and S. Nichols [1994]. “Developing a national spatial data infrastructure.” Journal of Surveying Engineering. 120(2), pp. 62-76.

Nichols, S. and John McLaughlin. "Building a National Spatial Data Infrastructure." CONSAS 93. Sun City, Bophuthatswana: Proceedings of a Conference of the Institute of South African Surveyors, 1993.

Norplan AS [2001]. Economics of EIS. The World Bank. (Accessed from the World Wide Web on 2nd March 2002. http://www.esi-africa.org/economics.html)
Rajabifard, A. et al. [2000]. From Local to Global SDI Initiatives: A Pyramid of Building Blocks. 4th Global Spatial Data Infrastructure Conference, Cape Town, South Africa.
The Economist, November 10 – 16th 2001. Technology and the Poor, pp50–.
Sedunary, M.E. [1993]. A Strategic Approach to Land Information Management. Computers, Environment and Urban Systems 17: 243–251.
Viergever, K. [2001]. Successful and Easy Implementation in Southern Africa? Spatial Data Infrastructure. GIM International, 15(4): 13-15 (April 2001)