A Tree Model for Diffusion of Spatial Data Infrastructures in Developing Countries

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ABSTRACT
The scope of implementation of Geographical Information Systems (GIS) has in the recent past shifted and exceeded the limits of corporate boundaries, primarily out of the need and desire to exchange spatial data across GIS systems installed in various institutions. Consequently, Spatial Data Infrastructures (SDI) have been developed to facilitate efficient and easy accessibility to geospatial datasets in an attempt to remove barriers to utilisation of Geographical Information Systems. From Global, through regional to national and local levels, interconnected SDIs have been developed mainly in developed economies. Developing countries in the process of developing SDIs are faced with a challenge of using models from the developed world and yet the operational environments significantly differ. This paper examines SDI Implementation models in developed regions and evaluates the underlying assumptions in the models. The paper indentifies that most of the assumptions in the models do not efficiently reflect the reality of the SDI implementation environment in developing countries such as Uganda. The paper final proposes an alternative SDI implementation model that is localised to the SDI implementation environment in Uganda. For simplicity, this model is referred to as a Tree Model so as to reflect the inter-dependence of SDI components at various levels of government. It is characterised by national institutions initially taking up the central role in the core activities of the SDI in the early stages of its diffusion.

Keywords: SDI, Tree Model, Uganda, GIS, Developing Countries

1.0 INTRODUCTION

The scope of implementation of Geographical Information Systems (GIS) has widened from standalone corporate systems to inter-connected systems at local, national, regional and global levels. Similarly, the definition and perception of GIS has improved from technology biased perspective to organizational and inter-organizational perspectives. Efforts to develop Geographical Information Systems are increasingly shifting towards creating data infrastructures for accessing and utilizing spatial data between various institutions.

The drive to develop spatial data infrastructures is dictated by the nature of GIS databases as well as the manner in which GIS analysis is conducted. GIS databases are composed of multiple layers of datasets representing fundamental datasets that cut across various institutions and thematic datasets that are specialized for specific institutions. Many GIS analyses are based on combining data from different layers to provide ranked solutions to a given problem. For example, the assessment of a wetland requires combining information on soils, vegetation, water quality and so on.

Rajabifard and Williamson (2000) point out that institutions in the process of developing GIS databases or intending to use GIS in their operations sooner or later find out that they:

(i) Require spatial data in excess of what they can afford to collect using their budgets;
(ii) Require spatial data that lie outside their jurisdictions, operational areas, institutional mandates or are unavailable to them, and
(iii) Are most likely to collect data which are incompatible with data held in other institutions.

The solution to the above bottlenecks in implementing Geographical Information systems appears to lie in establishment of infrastructures for sharing spatial datasets. Spatial data

sharing infrastructures or Spatial Data Infrastructures (SDIs) are synonymous to other infrastructures such as roads, power-lines and railway. The whole concept of SDIs, and other forms of infrastructure, is that they allow authorized and/or participating members of the community to use them. They are simply available and taken for granted, although their use may have to be paid for e.g. through vehicle registration, railway tickets. Because such infrastructures are, in many cases public goods, users take them for granted but the government has a responsibility to ensure that they are working. However, SDIs are necessary and inevitable infrastructures for GIS diffusion and hence their planning and implementation requires careful research and planning. SDI implementation models are part of SDI assessment research and as Grus (2007) observes, SDI assessment is an increasingly hot topic mainly because SDIs are established by governmental bodies and financed from the public funds.

2.0 THE PROBLEM

As would be expected, the need to coordinate efforts in GIS implementation was first realized in developed countries and this explains why initial efforts to develop spatial data infrastructures started in developed countries. As such, models for developing and sustaining SDIs as documented by several authors such as Giff and Coleman (2003) and Rhind (2003) are oriented towards operational environments in developed countries. The models, generally pre-suppose some level of autonomy and independence of local governments in terms of planning, reporting and financing. For example, it is assumed that local/federal governments are able to draw up their budgets and identify the sources of financing, with minimum intervention of higher-level governments. In reality, the salient factors that govern the choice of a model of an SDI for a government include ECA (2004):

- The nature of the economy;
- The general market environment;
- The maturity of the spatial data industry;
- Government policies;
- Availability of supporting infrastructure; and
- The influence of culture and availability of skilled work force

Clearly, the above factors vary across the world and generally fall within the global divide categorises identified by Mossberger et al. (2003) as: (1) the access divide, (2) the skills divide, (3) the economic opportunity divide, and (4) the democratic divide. These variations imply that models based on experiences from developed countries may not effectively apply in developing countries. Furthermore, even in the developed economies where most of the above factors are closely related, there is a certain degree of variation (Graham (2002) that require examination before an SDI implementation model that has been successful in one country can be transferred to another country or region. To the contrary, promoters of SDI development in Uganda and other developing countries appear to be advocating for SDI implementation models in the developed world without examining the specific environment where they are to operate. There is a potential risk that SDIs developed without considering the operational environment will at worst fail or at best not serve the purpose for which they are being developed and this will in the long run derail GIS diffusion in developing countries. This paper introduces a new model for implementing GIS in Uganda and similar developing countries based on examination of the operational environment.

3.0 OVERVIEW OF SDI IMPLEMENTATION MODELS

Although SDI is now an accepted concept, there is still no consensus on the components and the relationships between the components of an SDI. However from the definitions adopted by the major players in SDI development such as FGDC, INSPIRE, APSDI and others, the most acceptable and cross-cutting components of an SDI include (Nebert 2001; Rajabifard and Williamson 2001; Masser, 2005):

(1) Spatial datasets developed by institutions under their respective individual mandates but in agreed conformity standards;

(2) Technical standards prescribing structured approaches to development and access of data;
(3) Policies that guide access to data;
(4) Networks providing the means to access data;
(5) People/Institutions constituting partnerships for shared data spatial data development, accessibility and utilization.

The generic model of SDI development is a hierarchy with components at various levels of government and these serve the planning requirements at each level. The level of detail in spatial datasets and standards at each level should serve the planning requirements at that level. For example, SDIs at local level should aid detailed planning while SDIs at national level should serve broad planning at a smaller spatial scale with less details as illustrated in Figure 1.

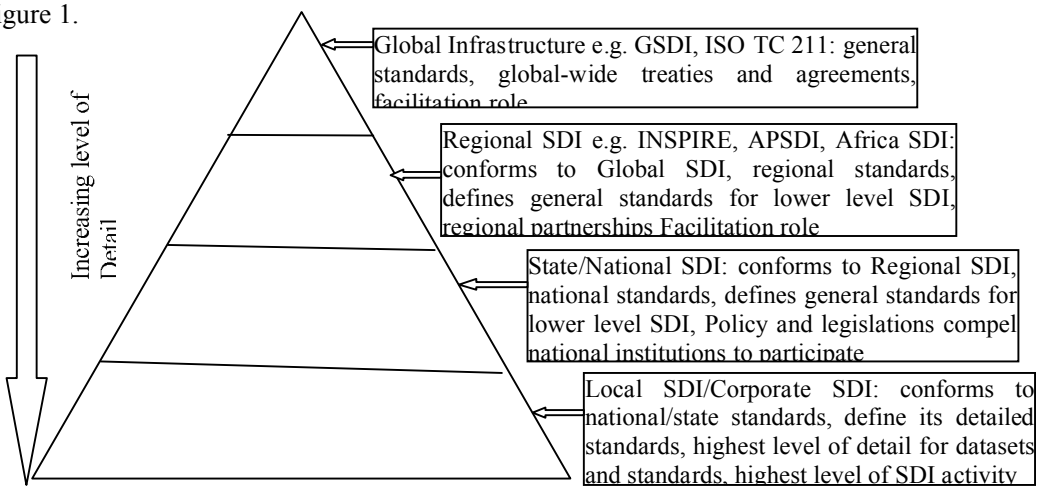

Figure 1: Pyramid of SDI roles and requirements at various implementation levels

Since the level of detail in spatial datasets is related to compilation (or map) scale, it would be expected that large scale or high spatial resolution datasets should be produced and maintained at the lowest level of SDI and these should be successively aggregated to develop coarser datasets at higher levels of SDI. On the basis of the arrangement, (Rajabifard and Williamson (2000) identify two different models (views) that have been used to describe the hierarchical structure of Spatial Data Infrastructures; namely, the Umbrella View and the Building Blocks View illustrated in Figure 2A and 2B.

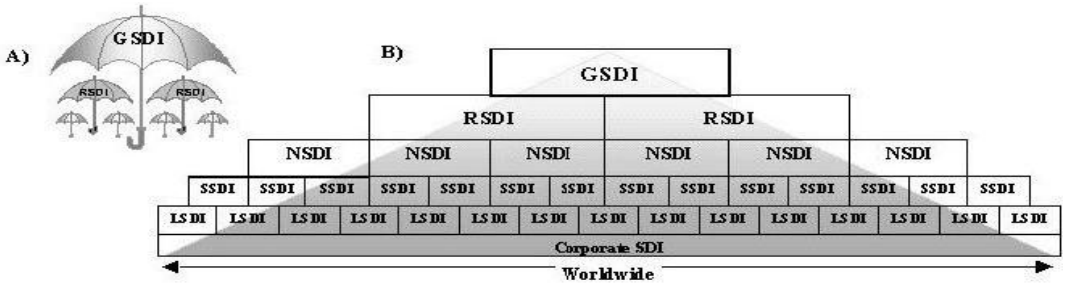

Figure 2: SDI Hierarchy: (A) Umbrella view (B) Building Blocks (Rajabifard A. and I. Williamson 2000)

The umbrella view examines the role of a higher level Spatial Data Infrastructure as that of facilitation in the accessibility of geospatial data that is maintained at lower Spatial Data Infrastructure levels. In other words, the higher level Spatial Data Infrastructure is developed to coordinate and support the activities of the lower level Spatial Data Infrastructures. Although it is not clear what facilitation as advanced by the authors would entail, by analysis of the existing SDIs, it can be inferred that it may include functions such as providing policy

and legal framework as well as defining general standards for developing lower level SDIs. An example is the INSPIRE which is a Europe-wide SDI, implemented through a directive issued in 2007 (INSPIRE 2007) compelling EU members states to harmonise standards for metadata, data specifications, network services, data and service sharing and monitoring and reporting. The purpose of this directive was to lay down general rules aimed at the establishment of interoperable national Infrastructure for Spatial Information in member countries.

Another example is the Asia-Pacific Spatial Data Infrastructure, a regional SDI which is an initiative of the national mapping agencies in Asia and the Pacific Region, undertaken to maximise the economic, social and environmental benefits of geographical information. This regional SDI is implemented through workgroups that define consistent standards and guidelines for member countries. The working groups include geodesy, regional fundamental data, development needs taskforce, communication and outreach.

At the global level, the Global Spatial Data Infrastructure (GSDI) is considered to be an attempt to create a world-wide infrastructure for sharing spatial data. Its purpose is to promote international cooperation and collaboration in support of local, national and international spatial data infrastructure developments in an Endeavour to have nations to better address social, economic, and environmental issues of pressing importance. The GSDI is envisaged to encompass the broad policy, organisational, technical and financial arrangements needed to support ready global access to geographic information.

Viewed in the umbrella perspective, the above Spatial Data Infrastructures are developed to facilitate the activities of lower SDIs to ensure that there is consistency in spatial data accessibility and utilisation. This appears to be the reason why the whole concept of the inter-relationships between the levels of SDI is described as the Umbrella view.

The building block view (Figure 2 B) on the other hand, considers the higher level Spatial Data Infrastructure as being composed of Spatial Data Infrastructure elements from lower level Spatial Data Infrastructures as building blocks. The lower level SDIs then contribute to the higher level Spatial Data Infrastructure in the hierarchy to enable decision-making at larger spatial coverage. While building the higher level Spatial Data Infrastructures, a lot of detail is left at the lower level and hence the higher level Spatial Data Infrastructure is less detailed but covers a larger geographical area. From the implementation perspective, this model presupposes that the SDI development starts at the lower level and grows in spatial extent to build a higher level SDI. In other words, it is the lower level SDI that facilitates the growth of the higher level SDI.

The two views of SDI hierarchy help to identify the manner in which SDIs are developed. However, the models do not address the interactions that exist between SDIs at the same level. For example, National Spatial Data Infrastructures for the facilitation of data exchange between neighbouring countries that share a common wetland system will have no interaction within the hierarchy. Yet it is necessary that data should be exchanged between these SDIs in order to carry out joint assessment and management of cross border wetland systems. As pointed out earlier, most of the current models for developing and sustaining are oriented towards operational environments of developed countries. The models, generally assume some level of autonomy and independence of local governments in terms of planning, reporting and financing. For example, it is assumed that local governments are able to draw up their budgets and identify sources of financing with minimum intervention from higher level governments.

4.0 SDI IMPLEMENTATION CONSTRAINTS IN UGANDA

Developing countries such as Uganda present unique SDI implementation environments characterised by a host of unique and differing constraints. Many of the constraints associated

with SDI components such as limited datasets, limited human resources, lack of metadata and institutional policies have been covered by authors such as Ezigbalike et al (2000). In addition to these challenges, Uganda and other developing countries are faced with a host of other challenges that include funding priorities, private-sector/government synergies, government administration structures, and technological infrastructure:

4.1 National and Donor Priorities

In developing countries with limited resources, the national budget usually gives priority to programs that cause a direct and tangible impact towards the improvement of livelihoods of the poor, the majority of whom live in rural areas. Therefore, investments such as construction of roads, hospitals, schools and extension of safe drinking water are more favoured, since they are easy to cite, while evaluating the performance of a government. This preference puts investments with long term and hidden benefits such as SDI, at stake, with virtually no possibility of attracting financing from the public funds. As a result, funding for SDI activities remains at the mercy of the donor community with limited support from the national government. In Uganda and many other countries, donors provide conditional grants targeting specific sectors at national or local level. This funding model has implications for SDI development in that some sectors at the same level of government remain unfunded while others are well funded. In lieu of this model of funding, a good consideration would be to build an SDI using funded sectors as building blocks (rather than Local SDIs) and diffuse it to other sectors at a later stage.

4.2 Private Sector

The role of the private sector in SDI development cannot be under estimated. As a matter of fact, one of the first geo-information infrastructures- the Canoggis (Groot 1997), was led by the private sector. In Uganda, the underdevelopment of the private sector, which would offer support to the spatial data industry, is just emerging. Although, a deliberate government policy on privatization has led to many state owned enterprises such as banks, telecommunications and electricity being sold or concessioned to private investors, most of the services such as mapping, water supply, land management, and planning are still in the hands of government. The private sector in the spatial information sector is very small, and not able to add value to spatial information products.

4.3 Government Structure

Many developing countries still lack self-sustaining local governments. For example, since 1967 Uganda has been governed as a republic with most of the powers concentrated at the centre. In the recent past, the Local Government Act (1998) reversed this trend and transferred most of the powers to the local governments at the district and sub-county level. However, in reality, local governments still depend on the central government for most of their operations. The Central Government appoints the technical head of the District Local Government (Chief Administrative Officer) and supervises most of the activities, including recruitment of staff. The funding for local government activities are provided mainly through conditional grants from the Central government. To account for the conditional grants, local governments are required to submit periodic reports to the central government. This scenario demonstrates that local governments are not independent in their operations and this has implications for an SDI model that assumes complete autonomy of local governments.

4.4 Internet Infrastructure

The spatial distribution and coverage of Internet infrastructure in Uganda is still low and restricted mainly to the urban centres. According to the International Telecommunications Union statistics, the rate of internet usage in Uganda in 2000 was estimated at 40,000 people (0.1% of the population) but grew to 500,000 people (1.7% of the population) in 2006 and to 2,000,000 (6.4% of the population) in 2008. This rapid growth is further evidenced by the availability of a growing number of commercial service providers, which will in the long run bring down the cost of accessibility to the internet. These figures are not comparable to

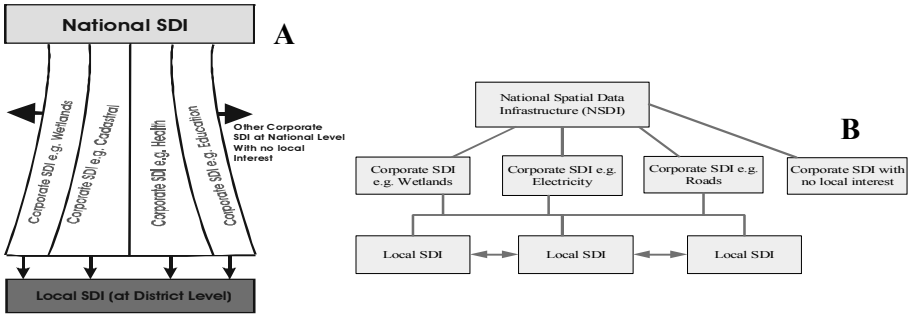

Figure 3Error! No text of specified style in document.: (A) Tree Model for SDI, (B)

developed countries such as Sweden whose usage is estimated at 8,397,900 users as of June 2010, which represents 92.5% of the population. In Uganda, most Local Governments are not yet connected to broad band internet and hence development of local SDI to link with National SDI is not yet feasible.

5.0 INTRODUCING THE TREE MODEL FOR SDI IMPLEMENTATION

An appropriate model for the SDI would be one that promotes sharing of data between national institutions, local governments, non–governmental organizations and the private sector taking into consideration the realties outlined in the above section. The desired model should initially adapt to the current linkages between local governments, central government departments and the private sector as other options for improving the linkages are sought.

In the current administrative setting, local governments, although mandated by both legislation and policy do not have adequate technical capacity nor financial ability to build components of an SDI. Therefore, institutions at the national level should play a bigger role in defining the specifications of the elements of local SDI such as common datasets and standards for spatial data as well as metadata. Since many local government departments in reality, posses vertical relationships with central government departments/institutions, the latter can impose and monitor conditions for SDI development through conditional grants. In effect, local SDIs should evolve through implementation of national niche SDIs, but should consider increased detail in both datasets and standard for lower level SDIs. This appears to be the model being followed by pioneer SDI activities such as the development of a Land Information system in Uganda. In this initiative, The Ministry of Lands Housing and Urban Development, a national Institution is developing detailed databases at district level which will feed into a national database. The above arrangement is a unique approach where national institutions with donor funds together with other corporate organizations including the private sector participate in the activities of SDI at local and national level. The evolving NSDI therefore is supported by individual contributions from the national institutions, but could also be used as a vehicle to solicit for external funding and capacity building. The national institutions maintain their vertical linkages with the local government departments and therefore share the corporate SDI with the local governments but at a larger spatial detail in respect of local governments. In other words, the national institutions help to build the local SDIs, which in turn support the national institutions with detailed spatial data. For simplicity, this model is referred to as a Tree Model (*see* Figure 3) so as to reflect the unique inter-dependence of SDI components at various levels of government. It consists of national institutions initially taking up the central role in the core activities of the SDI, but simultaneously developing all the components of SDI at local and national level. This involves capacity building at the Local Government level as well.

6.0 ROLE OF SDI COMPONENTS IN THE TREE MODEL

In the Tree Model Structure, the well-defined national corporate institutions act as stems and hence provide the initial membership on which the SDI thrives. The overall National Framework, in turn identifies the funding sources and avenues needed for the SDI activities

and sets up the basic technological infrastructure that includes computer access networks and capacity-building of the people component, with a view to strengthening corporate and local SDI and thereby acting as Leaves. The SDIs at the Local Government level then provide the base on which detailed spatial data is gathered in accordance with Standards developed at the national level. In this regard, they thus act as roots. The local SDI may, however, increase the extent of detail in the standards so as to cater for increase in the level of detail in the Spatial Data at the lower level of SDI. Enforcement of compliance by local governments with uniform and common standards is ensured through inclusion of compelling provisions in the Memorandum of Understanding (MOU) that is signed before release of the Conditional Grants from the Central Government to the Local Governments. This model differs from the other models in the extent of interaction between the SDIs at the various levels. Furthermore, it differs in the sense that in the Tree Model, the primitives for the National SDI are Corporate (niche) SDIs that maintain direct linkages with the local SDI s.

7.0 CONCLUSION

Development of SDI in development countries presents unique challenges that require to be examined before adopting a model for SDI implementation. In the case of developing countries such as Uganda which are faced with problems of spatial data availability, setting funding priorities, poorly funded and semi-autonomous local governments and limited human resources, the approach to SDI implementation should focus on achieving the generic objectives of Spatial data Infrastructures without necessarily following the trajectory of developed countries. A tree model proposed in this paper is a means to achieve this.

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