Assessing an SDI Readiness Index

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SUMMARY

Recent studies have been carried out to assess the development of national spatial data infrastructure (SDI) worldwide (Crompvoets et al., 2004; Kok and van Loenen, 2004; Hyman et. al. 2003). These studies have focused on countries that are implementing various components of SDI. A survey of national spatial data clearinghouses worldwide in 2003 (Crompvoets et al., 2004) depicted that 67 countries had a published version of a clearinghouse on the Web, 13 had clearinghouses in the process of being published, and 113 countries had yet to implement a national geospatial data clearinghouse. With the majority of countries yet to initiate clearinghouse activities, one is inclined to ask what the obstacles are that are impeding efforts. The goal of this work is to develop a model for assessing the obstacles for SDI development, particularly in developing countries, and to prioritize strategies for surmounting these obstacles.

Over the past decade, a range of best practices has evolved for spatial data infrastructure development, but these best practices cannot be equally applied in all countries due to organizational, technological, and financial differences inherent to the countries. Some countries demonstrate a "clonation" of NSDI from another country, but these do not necessarily have self-sustaining capacity. In a sense, the NSDI is a fictitious implementation, with the country not yet 'ready' to embrace SDI development.

The model proposed in this paper for determining an SDI readiness index integrates factors from several points of view: *organizational* (politicians vision-commitment-motivation, institutional leadership, national legal (umbrella) agreements); *information* (providers' motivation, digital cartography availability, knowledge of standards); *access network* (web connectivity; technological infrastructure, geospatial software availability/in-house development); *people* (educational level, SDI culture, individual leadership) and *financial resources* (government sources, private sources, national geospatial initiatives). The model is based on fuzzy logic, given the qualitative nature of the majority of factors.

The model was applied to the assessment of the SDI readiness index in Cuba in two time periods: in 1999, when the concept of SDI first arose in Cuba; and in 2005, when Cuba launched its National Geospatial Portal. The same methodology could be used to assess SDI readiness between countries within the same time period. This comparison of Cuba over time demonstrates an increase in SDI readiness. Although Cuba has made significant progress, the country still faces many challenges towards an effective implementation of a National SDI.

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1. INTRODUCTION

National Spatial Data Infrastructures (SDI) worldwide are evolving; new initiatives gradually put in place elements that contribute to the realization of Global Spatial Data Infrastructure (GSDI). A body of literature is developing on national and regional experiences. However, these studies often do not take into account the *evolutionary* nature of SDI development. It is important to have a *longitudinal* perspective when accessing SDI. Some countries attempt to clone SDI "recipes" from other countries, but they find there is no guarantee of sustainability. Best practices around the world cannot necessarily be applied equally in countries due to the differences (organizational, technological, financial, etc) between countries. These differences determine a country's readiness for SDI, some supporting and others impeding SDI development.

A number of countries, with no national SDI initiative in place, have yet to register on a scale of SDI implementation. Local conditions and obstacles obviously hinder SDI implementation, but potentially a different set of obstacles for each country. This is another reason for developing a methodology to distinguish the obstacles.

Without intending to oversimplify the SDI concept, some researchers have attempted to approximate the variation of SDI development through analysis of results obtained in a survey of national spatial data clearinghouses worldwide, published in 2003. The survey revealed that 67 countries had a published clearinghouse version on the Web, 13 had projects in the process of being published, and 113 countries had yet to conduct any initiative to build a national geospatial data clearinghouse (Crompvoets et al., 2004).

The Information Technology (IT) community, too, has conduced worldwide surveys to assess national variations. E-Readiness measurement exercises have been carried out, and a UN Global Survey to determine E-Government readiness (UNDESA, 2003) assessed 191 UN member states according to a composite index, based on website assessment, telecommunication infrastructure, and human resource endowment. Given the validity of these studies, based on their comprehensiveness, the methodology has been extended to evaluate factors integral to SDI development, such as web connectivity, telecommunication infrastructure, and human capacity.

An e-Readiness index could be defined as the degree to which a country is prepared to participate in the networked world. It demands the adoption of important applications of ICTs in offering interconnectedness between government, businesses and citizens (eTechnology Group, 2003). As an analogy, *SDI* readiness index could be defined *as the degree to which a country is prepared to deliver its geographical information in a community (local, national,*

regional or global). It demands a variety of geospatial services offered in the widest connectivity to satisfy government, business and citizen geoinformation needs.

2. STUDY METHODOLOGY

To create an SDI readiness index it is necessary to identify a wide spectrum of factors that influence SDI development, establish a hierarchy of priorities of these factor, and then discover their incidence in countries with respect to NSDI implementation. The scope of this study will consist of all countries. Initially, Cuba will be used as a case study. The objective is to develop a composite SDI readiness index and evaluate its use in selected countries. The index will provide a first step in identifying case-specific strategies to address SDI implementation obstacles.

The methodology used in this study consists of the following steps:
1. identify factors involved in the readiness of countries to undertake a National SDI.
2. design a model to determine the SDI readiness index.
3. assess the model in a case study.
4. refine the model in a worldwide census.
5. apply the SDI readiness index by means of a global survey.

The scope of this paper is limited to the three first steps; the work will continue with a worldwide ranking of SDI readiness and guidelines for interpreting the census results.

2.1 Factors involved in an SDI readiness index

To identify factors incident in an SDI readiness index, several previous studies were reviewed (Giff & Coleman, 2002) (Kok & van Loenen, 2004) (Crompvoets et al, 2004) (UNDESA, 2003) and as a result, the following global factors were identified:
- Organizational (politicians vision-commitment-motivation, institutional leadership, national legal (umbrella) agreements);
- Information (digital cartography availability, knowledge of standards);
- Access network (web connectivity; technological infrastructure, geospatial software availability/in-house development);
- People (educational level, SDI culture, individual leadership);
- Financial resources (government sources, private sources, national geospatial initiatives).

Another important aspect for consideration was the evaluation of national application scenarios (national programs of Information Society, environmental sustainability, poverty decreasing, land administration, disaster management), taking into account their catalyst influence over the other factors.

Sustainability capacity, too, was an important item to be evaluated, but it deserves an independent analysis considering its extension in time. The scope of this paper assumes, at a high level of abstraction, that stronger conditions at the onset of SDI development increase the likelihood of sustainability in the future, although we this issue will be dealt with in future

works. Special care is necessary with 'fictitious' SDI implementations that result from "SDI clonation", in which a target country does not inherit the self-sustainability capacity of the originator country.

2.2 Model to determine an SDI readiness index

To model the SDI readiness index, which is viewed as a multi-criteria decision making problem, it is necessary to disaggregate the global factors into several decision criteria iteratively until each decision attribute is defined. This process resulted in a decomposition represented in the Table 1.

Table 1. Decomposition of global factors of SDI readiness into decision criteria.

Factor	Decision Criteria
Organizational (O)	Politician vision (Ov)
	Institutional leadership (Ol)
	Umbrella legal agreement(s) (Oa)
Information/ Data availability (I)	Digital cartography availability (Ic)
	Metadata availability (Im)
People (P)	Human Capital (Pc)
	SDI culture-education (Ps)
	Individual leadership (Pl)
Access network (A)	Web connectivity (Aw)
	Telecommunication infrastructure (At)
	Geospatial software availability (As)/ own development (Ad)/ open source (Ao)
Financial Resources (F)	Government central funding (Fg)
	Data Policy aimed to return on investment (Fr)
	Private sector activity (Fp)

To evaluate each decision criterion, a truth-scale per categories used, as shown in Table 2. It is recommendable to assign values by means of group techniques in order to minimize the subjectivity of isolated points of view.

Table 2. Categories and values in the fuzzy model selected (Source: Espin, 2004).

Category	Truth Value
Absolutely False	0
Almost False	0.1
Too False	0.2
Rather False	0.3
More False than True	0.4
Equally False and True	0.5
More True than False	0.6
Rather True	0.7
Too True	0.8
Almost True	0.9
Absolutely True	1

A fuzzy-based model was chosen depending of the qualitative nature of some factors. According to this model, we can assume the following propositions:

- A country is ready to undertake an SDI if and only if it has an appropriated level of the global factors: Organizational, Informational, People and Financial Resources, and any level of Access Network.
  $SDI\ Readiness = O \wedge I \wedge P \wedge F \wedge A^{0.5}$
- A country has an appropriated level of organization to undertake SDI if and only if it has an appropriate level of: vision on SDI, institutional leadership and legal framework.
  $O = Ov \wedge Ol \wedge Oa$
- A country has an appropriated level of information to undertake SDI if and only if there is an appropriated availability of digital cartography and metadata or if there is not an appropriated availability of digital cartography then it has a strong level of metadata.
  $I = Ic \wedge (\neg Ic \rightarrow Im^2)$
- A country has an appropriated level of people to undertake SDI if and only if there is an appropriated level of: national human capital, SDI culture and individual leadership.
  $P = Pc \wedge Ps \wedge Pl$
- A country has an appropriated level of financial resources to undertake SDI if and only if there is an appropriated level of funding from the Government or from private sector or an appropriated level of return on investment from geospatial industry.
  $F = Fg \vee Fp \vee Fr$
- A country has an appropriated level of access network to undertake SDI if and only if there is an appropriated level of technological infrastructure, web connectivity and an appropriated availability of Geospatial software or own geoinformatics development or open source culture.
  $A = At \wedge Aw \wedge (As \vee Ad \vee Ao)$

Then the SDI readiness index based on Fuzzy Logic could be formalized by means of the following model:

$$SDI\ readiness = (Ov \wedge Ol \wedge Oa) \wedge (Ic \wedge (\neg(\neg Ic) \wedge (\neg Ic \wedge Im^2)) \wedge (Pc \wedge Ps \wedge Pl) \wedge (Fg \vee Fp \vee F) \wedge (At \wedge Aw \wedge (As \vee Ad \vee Ao))^{1/2}$$

A new multivalent logic system called Compensatory Logic useful for decision-making problems [Espin, 2004] is used to evaluate the fuzzy expression of the SDI readiness index due to its sensitivity with the variety. The only caution to take into account is in the case of the 0 value (absolutely false), because it means a veto.

Applying the compensatory logic, we obtain the following expression:

$$SDI\ readiness = (Ov*Ol*Oa)^{1/3} * (Ic * (Ic* ((1-Ic) * Im^2))^{1/2})^{1/2})^{1/2} *(Pc*Ps*Pl)^{1/3}*(1-((1- Fg)*(1- Fp)*(1- Fr))^{1/3}) *((At*Aw*(1-((1-As)*(1-Ad)*(1-Ao))^{1/3}))^{1/3})^{1/2}$$

3. ASSESSING THE SDI READINESS INDEX: CUBA CASE STUDY

The Republic of Cuba is an island nation located in the Caribbean that covers 109 886,19 square kilometers, with a population of 11 177 743 inhabitants reported in the last Population Census of 2002 (ONE, 2003). It is administered by a centralized government with fourteen provinces and 169 municipalities.

In 1999, the Hydrographic and Geodetic Service of Cuba identified the need to develop a National Spatial Data Infrastructure. At this time (T_1), no SDI initiative existed. At present in 2005 (T_2), Cuba launched the Geospatial Portal of the National SDI. This analysis over time provided a means for comparison. The same methodology could be used to assess and compare SDI readiness between countries within the same time period. The truth values for each decision criteria for each time period are provided in Table 3.

Table 3. Values assigned for the decision criteria; 1999 and 2005.

Factor	Decision Criteria	1999	2005
Organizational	Politician vision regarding SDI	0.2	0.7
	Institutional leadership	0.3	0.7
	Umbrella legal agreement(s)	0.4	0.6
Informational	Digital cartography availability	0.3	0.6
	Metadata availability	0.1	0.3
People	Human Capital	0.9	0.9*
	SDI culture	0.1	0.6
	Individual leadership	0.2	0.7

Factor	Decision Criteria	1999	2005
Access network	Web connectivity	0.1	0.166*
	Telecommunication infrastructure	0.05	0.051*
	Geospatial software availability	0.4	0.6
	Own geoinformatics development	0.5	0.8
	Open source culture	0.1	0.4
Financial Resources	Government central funding	0.3	0.7
	Return on investment	0.6	0.6
	Private sector activity	0.1	0.4

** These values are taken from UN Global Survey (UNDESA, 2003)*

Assessing the model of SDI Readiness Index in Cuba, the following results, shown in table 4, were obtained:

Table 4. SDI Readiness Index in Cuba:1999 and 2005.

Readiness of factors	1999	2005
Organizacional Index	0.23	0.66
Informational Index	0.22	0.44
People Index	0.26	0.72
Access Network Index	0.34	0.42
Financial Resources Index	0.38	0.58
SDI Readiness Index	**0.28**	**0.55**

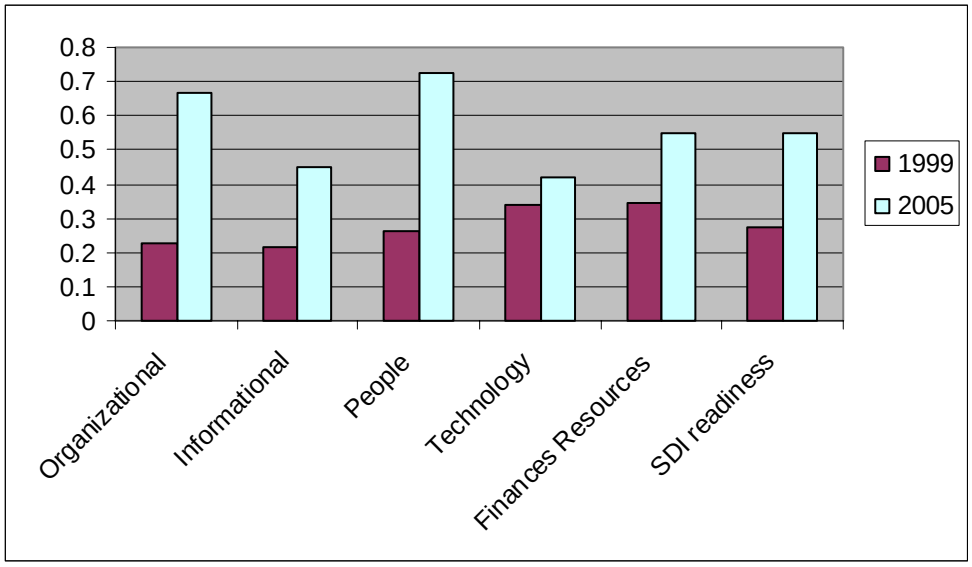

Figure 1. Comparison between factors and SDI readiness index in Cuba for 1999 and 2005.

The evolution of Cuba SDI readiness from 1999 to 2005 is evident. This period marks the time between the introduction of the idea to pursue SDI and the launch of Cuba's Geospatial Portal. The increase along the SDI readiness scale signifies considerable progress, but there is

room for plenty of improvement. The index helps to specify the barriers towards further implementation of a National SDI.

4. RECOMMENDATIONS TO SURMOUNT COMMON OBSTACLES

This study presents preliminary research on SDI readiness. It does not represent a comprehensive valuation based on the planned worldwide census. However, some recommendations can be made based at this stage. To do so, several scenarios combining decision factors at different levels were generated, with corresponding analysis.

Scenario 1. Countries with low SDI readiness index weighted by low availability of financial resources.

- associate the SDI to other national programs where geospatial management could be crucial (e.g., Information Society, disaster management, land administration).
- conduct cost/benefit analysis to emphasizing the merits of SDI to convince decision makers about the importance to invest in geospatial matters.
- orient the technological strategy towards Open Source in order to obtain free implementations of the geospatial standards necessary to build an SDI (Web Map Servers, Web Coverage Servers, Plug and Play GeoPortals, etc).
- find cheaper alternatives to share geospatial data bypassing the technological bottleneck (Delgado, 2005).
- explore alternative funding models for emerging nations (UNECA, 2004).

Scenario 2. Countries with low SDI readiness index weighted by low human capital, SDI culture, organizational barriers.

- encourage international capacity building projects, for instance, from GSDI or other international institution with authority in the topic.
- create national strategic alliance to reach a national SDI leadership.
- create a National Strategy to establish the SDI with annual programs to support a national legal framework.
- stimulate the natural individual leadership wherever it could be appreciated.

Scenario 3. Countries with low SDI readiness index weighted by low technological infrastructure.

- find alternative approaches to undertake National SDI tailored to the actual conditions of the country (for instance, centralized servers to concentrate the technological power and maximize the sharing of geospatial data and its performance) (Delgado, 2005).
- take advantage of the Open Source products distributed freely in the market place.

Scenario 4. Countries with low SDI readiness index weighted by low digital cartography availability.

- encourage the industry of production of digital cartography associating it with the main national programs (Information Society, disaster management, etc) or marketplace sectors (utilities, etc) where this information could be useful.

- encourage international capacity building projects oriented to cartography and geodetic industry, for instance, from ICA, FIG, ISPRS or other international institution with authority in the topic.

5. CONCLUSIONS

An SDI readiness index based on a model using fuzzy-compensatory logic provides a quantitative means to compare countries, as well as compare SDI progress over time within a country. The use of the SDI readiness index also helps to identify a strategy to address the primary obstacles of SDI development.
This is the first stage of this research aimed at characterizing the actual conditions of countries undertaking SDI development. Future work is necessary to obtain a Global Status of National SDI Readiness and to refine the methodology.

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BIOGRAPHICAL NOTES

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