Chapter 6

The Spatial Data Infrastructure Readiness model and its worldwide application

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Abstract. Since the Spatial Data Infrastructure (SDI) is strongly dependent on pre-existing infrastructures, it is necessary to understand some characteristics of these older infrastructures in order to understand SDIs. Another important issue for the SDI is its complexity, so sustainable SDIs can be developed when social, organisational and culture issues are resolved in harmony with the technological ones. With this in mind, the SDI readiness model has been developed, based on the assessment of some intrinsic issues of pre-existing infrastructures (WWW and communication infrastructure) and the analysis of other social, organisational and culture factors. This chapter focuses on methodological issues of the SDI readiness model and answers the questions of why, what and how this model has been developed. The second part presents the SDI readiness model application for 27 selected countries of different parts in the world. In addition, a hierarchical cluster analysis to identify relative homogeneous groups of countries is applied, using the values of SDI readiness indices. The results depict the main strengths and

weaknesses of the countries analysed, opening the possibilities to focus on the obstacles existing in the SDI initiatives worldwide. Finally, the main strengths and weaknesses of the SDI readiness model are presented and future works for improving the model are introduced.

6.1 INTRODUCTION

Spatial Data Infrastructure is a global phenomenon, evolving from inertia to necessity, especially in developing countries. So far, several SDI assessments have been conducted to measure the state or effectiveness of the SDI worldwide (Giff and Coleman, 2002; Hyman et al., 2003; Kok and van Loenen, 2004; Crompvoets et al., 2004). However, all these studies focus on assessing the performance or operational status, without taking into account the basic or pre-existing conditions to undertake an SDI in the countries assessed, or at least do not refer to this important issue.

From a historical point of view, SDI is a specialised manifestation of 'virtual infrastructures,' building on the top of pre-existing infrastructures. One of these is the Web, which, at the same time, depends strongly on older infrastructures that underlie it (Edwards et al., 2007).

Viewing National SDIs as an evolution of pre-existing infrastructures, it is necessary to evaluate the actual conditions of countries to design and implement effective SDIs at the national level. This approach argues the need to assess SDI readiness, or a composite index of the capacity and willingness of countries to use SDIs.

A first attempt to assess the SDI readiness approach was presented by Delgado et al. (2005) during the GSDI 8 Conference in Egypt. This presentation was limited to one case study to compare the progress of SDI readiness in one country ─ Cuba. The second attempt was the undertaking by Delgado and Delgado (2007) as part of an Iberian-American survey and assessed the SDI readiness of 15 countries.

At present, there is an initiative to integrate several approaches to assess SDI in order to create a continuum and monitoring evaluation system of SDI evaluation worldwide. In this new context, the approach of an SDI readiness index could contribute to:

- presenting a snapshot of the current status of SDI readiness in a selected number of countries in the world;

- providing a comparative assessment of the willingness and capacity of countries to undertake SDI; and
- providing a benchmarking tool for monitoring the progress of countries in their efforts to build SDI at a national level.

This chapter focuses on the SDI readiness methodology and the answers to the questions why, what and how the SDI readiness model has been developed. Finally, the chapter presents and discusses the main results of the last worldwide SDI readiness application, dealing with 27 countries around the world.

In addition, analysing a hierarchical cluster to identify relative homogeneous groups of countries is applied to the values of SDI readiness indices. This result depicts that best practices around the world cannot necessarily be applied equally in countries due to the differences (organisational, informational, technological, financial etc) among them. This result is also interesting as it highlights the main strengthens and weakness of the countries analysed, opening the possibilities to focus on the obstacles that exist with SDI initiatives worldwide.

6.2 THE SDI-READINESS MODEL

In order to obtain an index to measure SDI readiness, primary questions should be 'why', 'what' and 'how'.

6.2.1 'Why' in measuring SDI Readiness

The application of the SDI readiness model can contribute to identifying critical factors to undertake an SDI (Delgado et al., 2005). The knowledge about the level of these factors in each country could support coordinators and policy makers in developing successful strategies for establishing and maintaining national SDIs. Therefore the SDI readiness model could contribute to the enhancement of national SDIs in many countries.

An assessment of SDI readiness is meant to serve as an advisory tool and aims at:

- raising awareness in order to assure a reasonable basis for success in the SDI development process;
- discovering the main weaknesses of the environment in which SDI development takes place, as well the strengths;
- comparing levels of SDI readiness among countries or initiatives; and

- providing a monitoring and evaluation tool to assess the evolution of the conditions in a same country as well as the comparison of different countries regarding SDI development.

6.2.2 'What' in measuring SDI readiness

The SDI readiness index can be defined as a composite measurement of the capacity and willingness of countries to use SDIs. The index incorporates organisational, informational, human resources, technological and financial resources factors and the determination of the index value is based on a survey that only authorised experts of a country are able to complete.

Most of the factors that are included in the SDI readiness model are qualitative rather than quantitative. A basic seven tier classification system is used — from Extremely High to Extremely Low. The application of this classification is sufficient for obtaining the national data in the context of SDI readiness. The following are distinguished:

- Extremely High
- Very High
- High
- Medium
- Low
- Very Low
- Extremely Low

As already mentioned, the SDI index is built on the organisational, information, human resources, technology and financial resources indices.

Organisation Index

The 'organisation index' is a composite score consisting of three primary factors: politicians' SDI vision, institutional leadership and legal framework. The SDI vision deals with the awareness of politicians on the importance and development of a National SDI. Institutional leadership can be expressed as the coordination by one or more institutions of the national agenda regarding SDI. The legal framework considers the existence of any kind of national legal instrument (law, policy, directive, or agreement) to partly or completely support the development of the SDI.

Information Index

The 'information index' focuses of the availability of core spatial data sets (for example geodesy, elevation, cadastral, administrative boundaries, hydrography, transport, ortho-images and place names) as well as metadata.

Human Resources Index

The 'human resources index' is a composite score that incorporates the: human capital index, culture/education on SDI and individual leadership.

The human capital index itself is a composite score taken by the UN Report of e-Government Readiness (UNDESA, 2008) and is derived from the United Nations Development Program (UNDP) education index, comprising the adult literacy rate and the combined primary, secondary and tertiary gross enrolment ratio. It is a quantitative index.

The culture/education on SDI refers to the capacity building and the awareness of the impact of spatial data on the well-functioning of society. Businesses, public entities and academic institutions may ease the efforts to participate in the SDI and to acquire funding for SDI development. Investment of significant resources to build capacity and to raise community awareness of spatial data and technologies such as courses, workshops and seminars are important in realising the full potential of SDIs.

A critical issue for SDI development is individual leadership. An SDI needs one or more champions who lead its development. This kind of leader has to initiate an agenda building process and start to bring the community together. A leader can be appointed by a formal mandate, often a political support, or could act in an ad hoc way. A leader can also emerge from existing coordination activities, or from the achievements and enthusiasm of respected individuals, but for the sustainability of the SDI initiative this leadership should be institutionalised in some way.

Financial Resources Index

The 'financial resources index' is a crucial index that focuses on the sources of funding in order to develop an SDI. Funding is needed to finance, for example, the SDI-management and coordination costs, institutional framework, legal environment, hardware, (commercial) software, capacity building, metadata preparation and data collection.

Funding is a complex issue which includes many stakeholders and different funding arrangements. In this study, the financial resources measurement includes: governmental funding, cost recovery and private funding.

Technology Index

The access networks and technologies are critical from a technological perspective to facilitate the use of data and services from SDIs. They seek to facilitate access to relevant data sources and spatial information services by anyone, anywhere, in a ubiquitous environment.

The 'technology index' is composed by the communication infrastructure, the Web connectivity, the availability of commercial or in-house spatially-related software and the use of open source resources related to SDI.

The Web connectivity index is also taken by the UN Report of e-Government Readiness (UNDESA, 2008) and constitutes a score derived from a quantitative analysis of the national web presence of the 191 member states. The research team used a survey instrument with more than 200 indicators to assess the national government websites (at least one and in many instances two national websites/portals were identified and assessed for each country) along with five ministry sites which align with the UN Millennium Development Goals (these ministries include education, health, labour, social welfare and economic development/finance).

The availability of commercial, or in-house spatially-related software, is a measurement of existing basic software platforms to develop SDIs.

The measurement of the use of open source software is particularly important in developing countries as it is a key factor of technological sustainability, particularly when the financial scenarios change.

6.2.3 'How' in measuring SDI Readiness

Depending on the qualitative nature for the majority of the decision criteria, a fuzzy-based model, supported by a new multivalent logic system called Compensatory Logic (Espin et al., 2004), was chosen. According to the Compensatory Logic, the core of the SDI Readiness Model is a propositional system generated by SDI experts.

A proposition set was assumed in an iterative process to define SDI readiness and also each SDI readiness factor (see Table 6.1).

Then, the SDI readiness index, based on fuzzy logic, was formalised by means of the following disaggregated model:

$$\text{SDI readiness} = (Ov \wedge Ol \wedge Oa) \wedge (Ic \wedge Im) \wedge (Pc \wedge Ps \wedge Pl) \wedge (Fg \vee Fp \vee F) \wedge (At \wedge Aw \wedge (As \vee Ad \vee Ao))^{0.5}$$

The compensatory logic was applied, where the conjunction was solved by:

$$c(x_1,x_2,\ldots,x_n) = (x_1 * x_2 * \ldots x_n)^{1/n}$$

and the disjunction by:

$$d(x_1,x_2,\ldots,x_n) = 1 - ((1-x_1) * (1-x_2) * \ldots (1-x_n))^{1/n}$$

Finally, the following expression was obtained:

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

Table 6.1: SDI Readiness propositions set based on fuzzy-compensatory logic

Factors of readiness	Proposition	Logical model
Organisation	A country has an appropriate level of organisation (O) to undertake SDI if and only if it has an appropriate level of: vision on SDI (Ov), institutional leadership (Ol) and legal framework (Oa)	$Ov \wedge Ol \wedge Oa$
Information	A country has an appropriate level of information (I) to undertake SDI if and only if there is availability of digital cartography (Ic) and metadata (Im) [1]	$I = Ic \wedge Im$
Human Resources	A country has an appropriate level of human resources (P) to undertake SDI if and only if there is an appropriate level of: national human capital (Pc), SDI-culture (Ps) and individual leadership (Pl)	$Pc \wedge Ps \wedge Pl$
Financial Resources	A country has an appropriate level of financial resources (F) to undertake SDI if and only if there is an appropriate level of funding from the Government (Fg), or from the private sector (Fp), or an high level of return on investment (fr) from the geospatial industry	$Fg \vee Fp \vee Fr$
Technology	A country has an appropriate level of technology to undertake SDI if and only if there is an appropriate level of technological infrastructure, web connectivity and availability of geospatial software, or own geo-informatics development, or open source culture	$At \wedge Aw \wedge (As \vee Ad \vee Ao)$
SDI	A country is ready to undertake an SDI if, and only if, it has an appropriated level of the general factors: Organisational, Informational, People and Financial Resources, and any level of Access Network	$O \wedge I \wedge P \wedge F \wedge A^{0.5}$

[1] The Information readiness proposition has been redefined from Delgado et al. (2005), weighting digital cartography and metadata at the same level.

6.3 ASSESSING SDI-READINESS IN SELECTED COUNTRIES

In this study, 27 countries from Latin-America, The Caribbean, Europe, Asia and North-America were analysed thanks to the 'Multi-view framework to assess National Spatial Data Infrastructures' survey that was undertaken by the project consortia 'Development of Framework to Assess National Spatial Data Infrastructures' of Dutch program 'Space for Geo-information' and 'Evaluating and strengthening Spatial Data Infrastructures for sustainable development

in Latin-America and the Caribbean' of Iberian-American program of Science and Technology for Development (CYTED IDEDES).

The countries integrally studied are Argentina, Barbados, Brazil, Canada, Chile, Colombia, Cuba, Denmark, Dominica, Dominican Republic, Ecuador, Granada, Guyana, Jamaica, Malaysia, Mexico, The Netherlands, Nepal, Norway, Poland, Serbia, St. Lucia, St. Vincent, Spain, Trinidad & Tobago, Turkey and Uruguay.

The following Figures (6.1 Organisation Index; 6.2 Information Index; 6.3 Human Resources Index; 6.4 Financial Resources Index; 6.5 Technology Index) show the behaviour of the factors in the countries analysed using the fuzzy-compensatory model described.

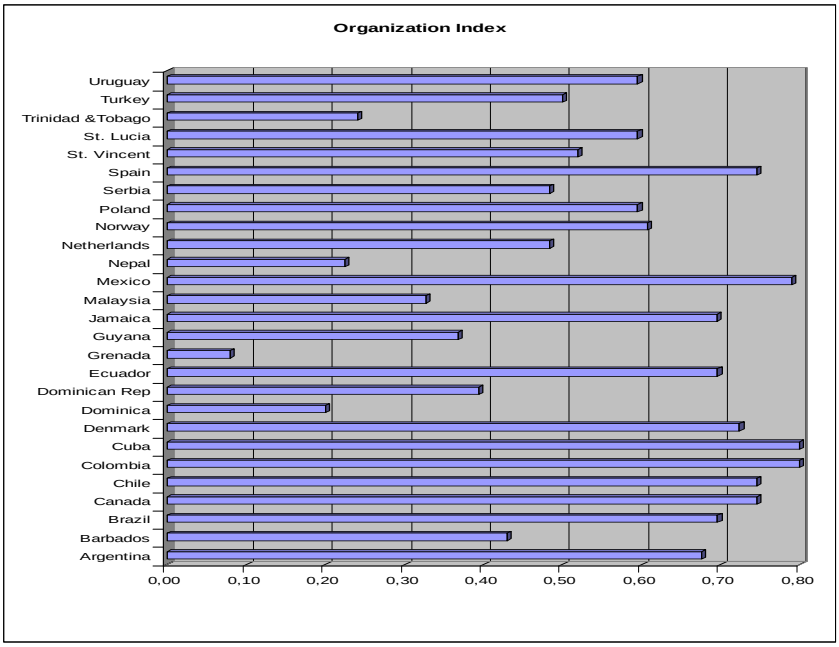

Figure 6.1: Organisation Indexes for countries selected

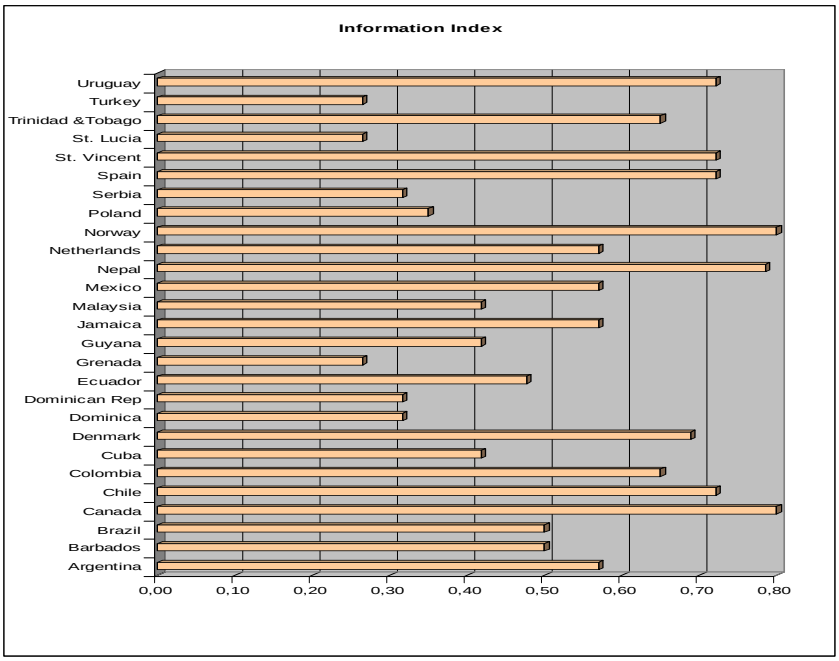

Figure 6.2: Information Indexes for countries selected

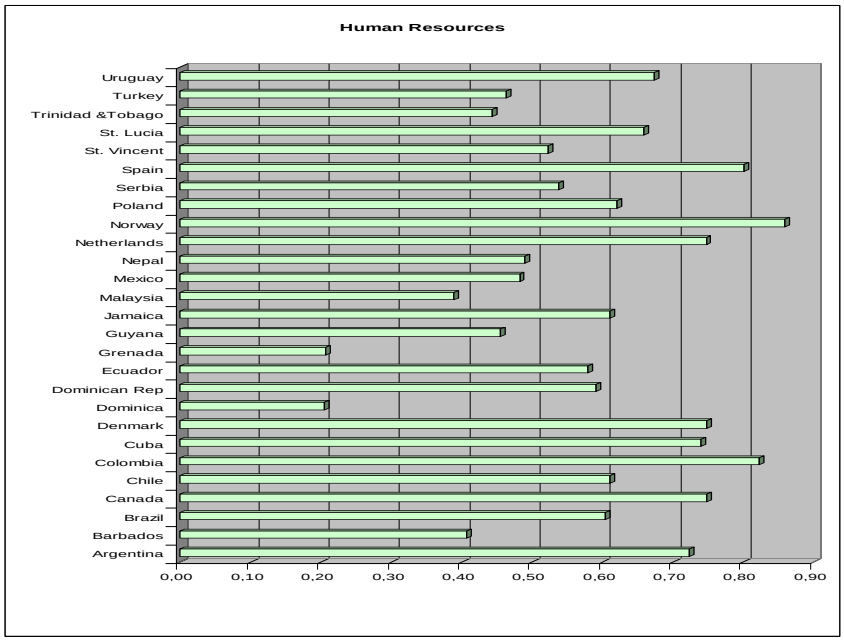

Figure 6.3: Human Resources Indexes for countries selected

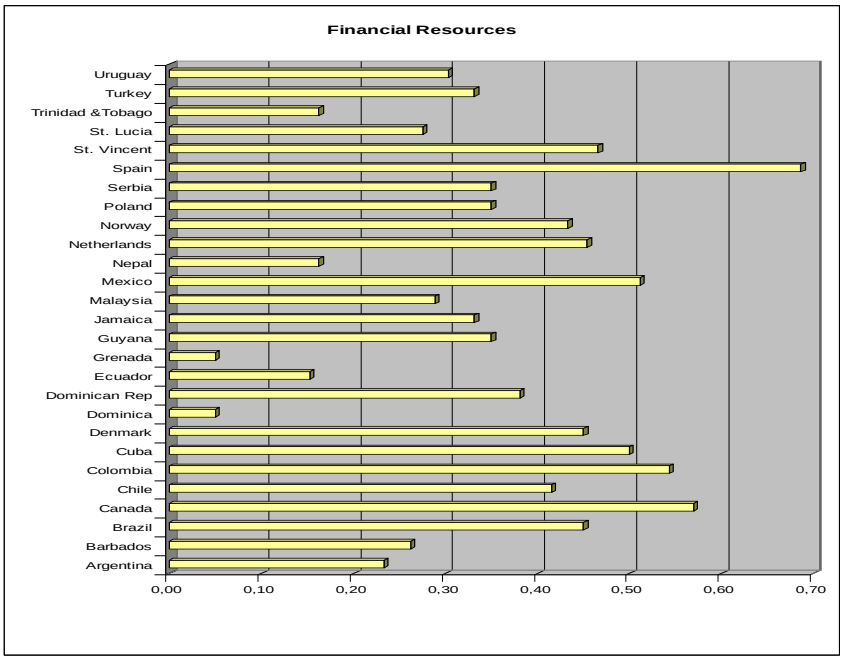

Figure 6.4: Financial Resources Indexes for countries selected

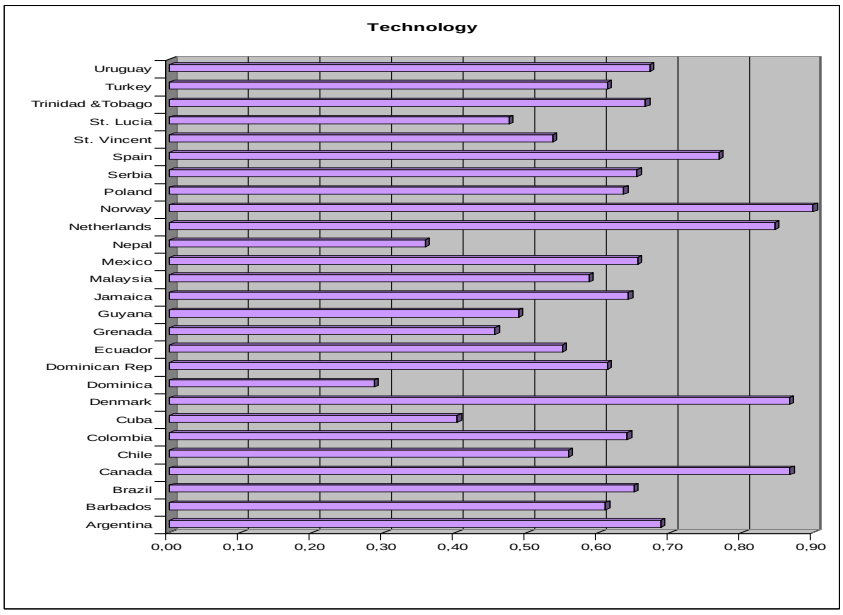

Figure 6.5: Technology Indexes for countries selected

As Figures 6.1, 6.2, 6.3, 6.4 and 6.5 indicate, there is a high dispersion of the behaviour between the different factors. The figures depict SDI as not a simple phenomenon but rather it should be seen like a multi-criteria problem strongly based on the combination of different factors. For instance, the technology behaviour seems to be related to income, in opposition with the organisational factor which has a very different behaviour regarding incomes. This difference demonstrates the importance of taking into account SDI readiness, not only technological issues, but also organisational, informational, financial and human factors into a composite integrator readiness index. Once again, it is important to highlight the organisation (and others as human and financial factors) as key to the success of an SDI, supported by the theory (Edwards et al., 2007) that infrastructures are basically coordination-based in opposition with systems that are basically control-based. A stronger legal framework aims to strengthen the coordination role so a more powerful and sustainable SDI is developed.

The following top countries, per factor, were identified at the moment of this research:

- Organisation ─ Colombia, Cuba
- Information ─ Canada, Norway
- Human Resources ─ Norway
- Financial Resources ─ Spain
- Technology ─ Norway

A more detailed discussion on the SDI readiness results, as a composite index which integrates all the factors into a model, is presented in the next section.

6.3.1 SDI Readiness and Cluster Classification

As the last step in the methodology, the SDI readiness index was calculated for each country obtaining the ranking as expressed in the Figure 6.6.

Comparing this one with the last evaluations based on SDI readiness (Delgado and Delgado, 2007), the majority of countries analysed are putting in place new systems and processes to strengthen their capacities and provide better service delivery through enhanced Spatial Data Infrastructure initiatives.

Finally, a hierarchical cluster analysis to identify relative homogeneous groups of countries was applied to the values of SDI readiness, resulting in several classes as shown in Figure 6.7.

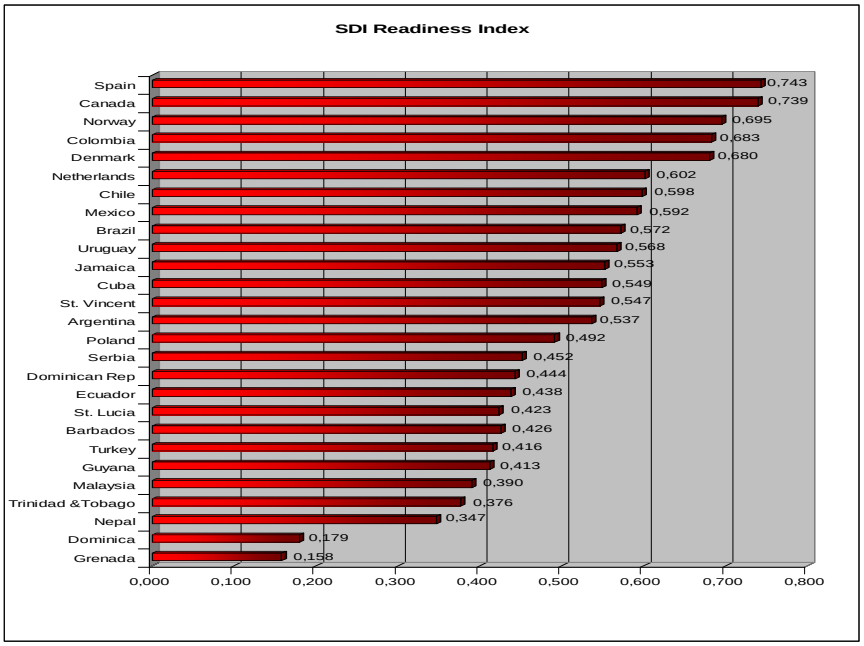

Figure 6.6: SDI Readiness Indexes for countries selected

From Figure 6.7, it is possible to identify four classes with relative homogeneous behaviour as follows:

- Class A: Spain, Canada, Colombia, Norway and Denmark
- Class B: Chile, The Netherlands, Mexico, Argentina, St. Vincent, Uruguay, Jamaica, Cuba and Brazil.
- Class C: St. Lucia, Turkey, Trinidad & Tobago, Nepal, Barbados, Guyana, Malaysia, Ecuador, Dominican Republic, Serbia and Poland.
- Class D: Dominica and Grenada.

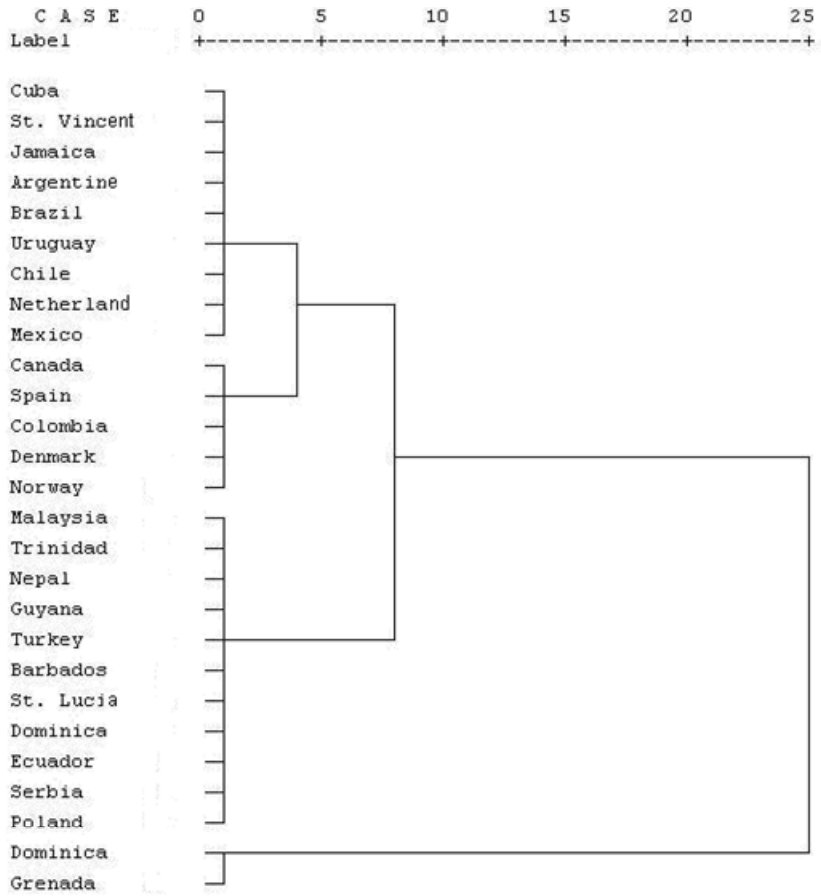

Figure 6.7: Hierarchical cluster diagram of SDI readiness

SDI Readiness Class A

In the top of the ranking list are Spain and Canada. The evolution reached by Spain in the last years deserves special attention. Recently, Spain has undertaken interesting initiatives which demonstrate its strong SDI strategy. The IDEE (Spanish SDI) is strengthening their legal framework by approving the following two documents in the last months:

- The Ministry Order 956/2008 on Data Diffusion Policy of IGN-CNIG (Ministerio de Fomento, 2008); and
- The Royal Decree 1545/2007 defining the National Cartographic System (Ministerio de la Presidencia, 2007)

An IDEE blog has been operating (http://www.blog-IDEE .blogspot.com) to increase the participation and communication of the initiative. This action forms part of the collaborative approach established into the framework of IDEE that is based on cooperation among National Government Ministries, Autonomous Communities, Local Governments, Universities, Companies, individual collaborators and citizens.

Other top countries of this class, such as Norway, Colombia and Denmark, also present a long term strategy and strong collaborative agreements to underpin their SDI initiatives, which can be an indicator of the importance of the organisational factor. As Figures 6.1-6.5 show, the countries of Class A lead in most of the factors justifying their high SDI readiness as an integrator indicator.

SDI Readiness Class B

This class is possibly the most interesting as it groups countries with different performance regarding incomes or other traditional indicators to compare general society development. However the countries have relative homogeneous characteristics according to the SDI readiness. In general, these countries exhibit high values in some factors, but they have also some low values in the other ones. Class B includes countries of almost all regions analysed. In this same class, there are countries classified with relatively high technological indices such as The Netherlands, Chile, Mexico or Brazil, and others with less developed technological infrastructures such as Cuba or St. Vincent.

SDI Readiness Class C

The same as for class B, this group includes countries with some SDI readiness strengths in contraposition with weaknesses, but have lower values in SDI readiness. This is the group that contain the highest number of countries at eleven countries. It is notable that most of the countries are included into Classes B and C, in a middle interval whit an average behaviour.

SDI Readiness Class D

This class corresponds obviously with the two countries (Dominic and Granada) that have the lowest values. The determinants in this are the low values obtained by them for the organisation, human and financial resources factors. This result is very important for these countries. In the first place, they demonstrate their interest to improve their SDI initiatives by the fact that they completed the SDI-readiness survey. On the other hand, they can now take advantage of the best practices

of other SDIs, once they have identified their main weaknesses, and their awareness of the situation has been raised.

6.4 LIMITATIONS AND STRENGTHENS OF THE SDI READINESS MODEL

This chapter shows the main strengths of the SDI readiness model based on a fuzzy-compensatory logic, summarised by the following characteristics:

(1) possibility to integrate qualitative and quantitative factors;
(2) simplicity of model to the decision makers due to the semi-natural language used to express the propositions; and
(3) flexibility and adaptability to possible changes of the propositional model without affecting the primary values of factors.

Moreover, the application with this model has demonstrated the need to improve it, based on the following facts or limitations:

(1) propositional system should be collegiate by a broader SDI international group of experts;
(2) factors should be analysed in the context of new ongoing research based on the multiple perspectives to evaluate SDIs; and
(3) necessity to minimise the subjectivity of the answers by designing better questionnaires and applying decision making group techniques.

These limitations should be taken into account in future works improving the SDI readiness model.

6.5 CONCLUSIONS

The multi-factorial analysis carried out in this chapter demonstrated that SDI readiness is not a simple phenomenon; rather it should be seen like a multi-criteria problem strongly based on the combination of different factors. The results confirm the importance to take into account in 'SDI readiness' and not only technological issues but also organisational, informational, financial and human factors into a composite integrator readiness index.

An interesting finding is that SDI readiness can not be replaced by incomes or other global indicators, due to the multi-criteria nature of SDI readiness and its strong relation with organisational and co-ordination issues.

Despite the different SDI readiness behaviours of the countries analysed, the majority of these are putting in place new systems and processes to strengthen their capacities and provide better service delivery through enhanced SDI initiatives.

Finally, it is strongly recommended: to improve the SDI readiness model by redefining the propositional model and the factors involved; to continue the monitoring the SDI readiness and compare more countries worldwide.

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