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Research Article

Assessing the worldwide developments of national spatial data clearinghouses

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Abstract. Many countries have spent considerable resources over the past few years debating optimal national spatial data infrastructures. One of the (main) elements of these infrastructures is the national spatial data clearinghouse, which facilitates access to required spatial data and provides complementary services. With this in mind, in April 2000, 2001, 2002 and December 2000, 2001, 2002, a web survey was carried out to assess systematically the developments of these national clearinghouses worldwide. Regarding the development in the number of implementations, it can be considered a worldwide success. However, of concern are the declining trends in use, management and content. One of the main reasons for these negative trends could be the dissatisfaction of the spatial data community with the functional capability of current clearinghouses. The functional capabilities of clearinghouses should likely be changed from a data-oriented to a user and application-oriented focus. This is in accord with the objectives of the second generation of spatial data infrastructures. The main factors, therefore, that will have positive impacts on developments in this field are the inclusion of web services, stability of funding and creation of user-friendly interfaces.

1. Introduction

Spatial Data Infrastructure (SDI) is about the facilitation and coordination of the exchange and sharing of spatial data between stakeholders in the spatial data community. With this objective in mind, many countries are developing SDI to manage and use their spatial data assets more efficiently. These countries are finding it necessary to develop SDIs to assist in decision-making that has an important impact within their national boundaries. Over the past few years, many countries have spent considerable resources on debating optimal National SDI (NSDI). One of the main elements of a NSDI is the national spatial data clearinghouse (McLaughlin 1991, Clinton 1994, FGDC 1997, 2002, Coleman and

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McLaughlin 1998, Onsrud 1998, Groot and McLaughlin 2000, AUSLIG 2001). The national clearinghouse is the access network of an NSDI that facilitates access to the spatial data. It provides complementary services and improves the exchange and sharing of spatial data between suppliers and users.

Based on an overall assessment, the average cost of a spatial data clearinghouse (including some services) is around €1.5 million a year (INSPIRE Architecture and Standards Working Group 2002). This money is spent in management and coordination costs, GIS and Internet application development, training, hardware, network server, standardization activities, legal environment creation, and metadata preparation. Currently, 67 national clearinghouses have been implemented and 13 countries have projects for implementation. Based on these 80 initiatives, it means that globally around €120 million worldwide is spent yearly for clearinghouse management. Up to now, this money has never been audited or evaluated (certainly not globally).

Since 1994, a fast development in national clearinghouse implementation has taken place throughout the world. Not many studies exist about the worldwide development of these national clearinghouses. To the best of the authors' knowledge, no systematic periodical survey has taken place with regard to the development of national clearinghouses (Crompvoets 2002). The purpose of the present paper is to fill this gap, its main objectives being to assess worldwide developments, to analyse and describe these developments, to understand the reasoning behind them and to determine the critical factors for success.

This paper assesses and presents the developments of all national clearinghouses throughout the world, with reference to the concepts, definitions and history of SDI and clearinghouses. The assessment methodology has been described based on a longitudinal survey and the main development results are presented using the main SDI components: policy, access network, standards, people and data. Additionally, these development results are discussed and some key factors for success are determined.

2. Spatial data infrastructures and clearinghouses

2.1. *Spatial Data Infrastructures (SDIs)*

Viewing the core components of SDI as policy, access networks, technical standards, people (including partnerships) and data, Rajabifard *et al.* (2002) suggested that different categories could be formed based on the different nature of their interactions within the SDI framework. Considering the important and fundamental role between people and data as one category, a second can be considered consisting of the main technological components: the access networks, policy and standards. The best example of access network is the clearinghouse. The nature of both categories is very dynamic due to the changes occurring in communities (people) and their needs, as well as their ongoing requirement for different sets of data. Additionally, with the rapidity with which technology develops, the need for the mediation of rights, restrictions and responsibilities between people and data are also constantly subject to change (figure 1). This suggests an integrated SDI cannot be composed of spatial data, value-added services and end-users alone, but instead involves other important issues regarding interoperability, policies and networks. This in turn reflects the dynamic nature of

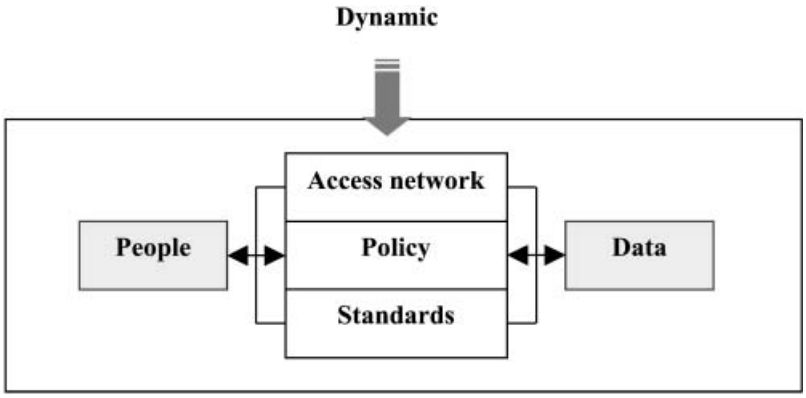

Figure 1. Nature of and relations between SDI components (adopted from Rajabifard *et al.* 2002).

the whole SDI concept. It is an issue also highlighted by Groot and McLaughlin (2000).

The concept of SDI can be defined as an integrated, multilevelled hierarchy of interconnected SDIs based on partnerships at corporate, local, state/provincial, national, regional (multinational) and global levels. This enables users to save resources, time and effort when trying to acquire new datasets by avoiding duplication of expenses associated with the generation and maintenance of data and their integration with other datasets.

With this in mind, every nation undertakes to some extent the development of strategic national mapping and spatial data activities to meet their national planning and management needs. The accumulation of these activities over time has resulted in the identification of key linkages between institutional and technical aspects similar in many respects to other forms of infrastructure, and occurring in a continuum of development strategies. Based on this, Rajabifard *et al.* (2003) distinguished and reported on two generations of SDIs, the first and the second generations.

The first generation of SDIs development has emerged since the mid-1980s when the USA and Australia, for example, started to develop the data access relationships, which became the precursor to the development of NSDI initiatives. At this time, countries developing SDI on any jurisdictional level had only very limited ideas and knowledge about different dimensions and issues of the SDI concept, and rather less experience of such development.

Within this generation, each country designed and developed SDI based on their specific requirements and priorities and nationally specific characteristics. The ultimate objectives of the SDI initiatives in this generation as summarized by Masser (1999) were to promote economic development, to stimulate better government and to foster environmental sustainability. A significant milestone overcome by the first generation, for whom there were few experiences and existing SDI developments from which to learn, was the documentation of researchers' and practitioners' experiences and status reports on their SDI initiatives and as part of that report on their clearinghouse activities which facilitated their SDI initiatives. This achievement not only gave countries a knowledge-base from which to learn and/or develop their initiatives, providing exposure to the developmental strengths

and weaknesses of different SDI initiatives, but also provided social capital to share and foster SDI developments in other countries. Consequently, many countries involved in SDI development over the first generation took a product-based approach, which became the dominant model for SDI justification and development partially through a lack of awareness of other options.

However, the transition to the second generation can be marked by a change in focus on SDI development by several countries (Australia, USA, Canada) involved in developing the concept from the beginning. This led to a rapid increase in the number of countries becoming involved in SDI development, fostered by the definition of an SDI community where experiences could be shared and exchanged experiences. This shows the continuum of strategic spatial data development.

The second generation started around 2000 when some of the leading countries on SDI development changed their development strategies and updated their conceptual models. In second-generation SDI, the strategy for SDI development is changing towards a more process-based approach (Rajabifard *et al*. 2003). This approach focuses on the creation of a suitable infrastructure to facilitate the management of information assets instead of the linkage to existing and future databases.

The second generation of SDI developments characteristically falls into two groups: those countries that started to develop an SDI initiative during the period of the first generation and are gradually modifying and upgrading the initiative, as well as those countries that have recently decided to design and develop an SDI for their respective countries and/or have just commenced doing so (Lance and Hyman 2001, Wehn de Montalvo 2001).

The distinguishing features of the second generation include leverage of the experiences, expertise, social capital of SDI development and the development of clearinghouse systems derived from the first generation. For the first generation, data were the key driver for SDI development and the focus of initiative development. However, for the second generation, the use of that data (and data applications) and the need of users are the driving force for SDI development. Introduction of web services is the main technological indicator of second-generation SDI because such services are partly able to fulfil the needs of users and improve the use of data. In summary, second-generation SDI development has been relatively quick due to the concept gaining momentum and because of the existence of early prototypes, clarification on many initial design issues, increased sharing and documentation of experiences to facilitate implementation and face the complexity of decision-support challenges.

2.2. *Spatial data clearinghouses*

A spatial data clearinghouse can be defined as an electronic facility for searching, viewing, transferring, ordering, advertising and/or disseminating spatial data from numerous sources via the Internet and, as appropriate, providing complementary services. Such a clearinghouse usually consists of a number of servers that contain information (metadata) about available digital data.

A clearinghouse is based on a distributed network of people (spatial data suppliers, managers and users) linked electronically (Clinton 1994, FGDC 2002). The term ‘distributed system’ refers to a distributed collection of users, data, software and hardware, whose purpose is to meet some predefined objectives (Bishr

and Radwan 2000). The clearinghouse allows suppliers to make known what spatial data exist, the condition of these data and instructions for accessing these data. Each data supplier describes available data in an electronic form and provides these descriptions (or metadata) to the network using a variety of software tools. Additionally, the data supplier can offer access to his produced data. Users can discover who has what spatial data and their type and quality (Radwan 2002).

The main reason for creating a clearinghouse is the desire of users to have a single source for accessing all the available resources. A spatial data clearinghouse is a system to provide this capability serving as a central point for sharing data among data producers and users (Phillips 1998, Noori-Bushehri and Rajabifard 2001, Rajabifard 2002).

To make a clearinghouse as the access network operational within an SDI, it has to be strongly linked to the other SDI components: people, data, policy and (technical) standards (Rajabifard and Williamson 2001). A clearinghouse can only be a success within an SDI when there is a strong cohesion between these components. The use, management and supply of data and the content, and/or quality of these data determine its success subject to the quality of the standards, response time of the clearinghouse and legal/economical policy.

There are different understandings of the definition of clearinghouses. The Australia and New Zealand Land Information Council (2000) defines clearinghouses in a much wider context. It incorporates: discovery, transfer and access services; legal arrangements including supporting custodians' ability to control access to their data; coordination and management functions; and the spatial information commercial market place in which data are value-added and integrated to produce products, services and solutions. The definition of the US Federal Geographic Data Committee (FGDC 1997) includes besides the technical mechanism also the institutional aspect of clearinghouses. However, mainly out of practical reasons, this paper focuses on the most tangible product of the clearinghouse; the electronic facilities for discovery, transfer and access.

The latest definitions of the clearinghouse play more emphasize on the inclusion of services. For example, the position paper of INSPIRE Architecture and Standards working group (2002) describes a clearinghouse (Portal) as a site featuring a suite of commonly used services, serving as a starting point and gateway to the Web for a user community. This service-oriented approach is in accord with the objectives of the second generation of SDI. Examples of services which could be included within a clearinghouse environment are: map service, coverage service, feature service, gazetteer service, coordinate transformation service, authentication service, analysis/spatial data fusion service; web pricing and ordering service. These web services will change the implementation of clearinghouse functional capability, as well as the way in which users use them in their own applications (Bernabé *et al.* 2002).

A national clearinghouse for spatial data is a central web-portal at national/federal level that focuses on the facilitation of spatial data discovery, access, and services recognized (in legal or institutional sense) by the national government (mainly through the national council for geo-information) as the country's main clearinghouse for spatial data. It is not a national repository where datasets are stored. It aims to be a kind of shopping mall for all national-wide available spatial

data as acquired by main (national) governmental agencies and/or industrial bodies. It is important to know that many differences in implementations exist. The way a national clearinghouse is set up depends on its technological, legal, institutional, cultural, commercial environment and management. This environment determines to what extent the clearinghouse management retains control over their products. Besides national clearinghouses, there are clearinghouses at the local, state and regional levels. The national clearinghouse is different from the others in the sense that it is embedded in the nation's institutions and legal framework. Examples of national clearinghouses are: USA, National Geospatial Data Clearinghouse; Australia, Australian Spatial Data Directory; UK, GIgateway and the Netherlands, Nationaal Clearinghouse Geo-Informatie.

The US Federal Geographic Data Committee (FGDC) established the first national (federal) clearinghouse in 1994. The implementation of this clearinghouse among federal agencies was motivated by a desire to minimize duplication of effort in the collection of expensive digital spatial data and foster partnerships where common needs exist (Rhind 1999, FGDC 2000). At this moment, the FGDC focuses on the extension of the clearinghouse network that provides 'one-stop' access to standardized spatial data, applications, programs and products from all federal agencies and incorporates similar non-federal information, and it establishes web mapping and online data services to meet general requirements of government and citizens users. After initial deployment and testing of the comprehensive web portal, reusable commercial replication services will be required (FGDC 2002).

3. Survey methodology

To assess national clearinghouse developments around the world, a longitudinal web survey was undertaken whose main intention was to examine the developments of all existing national clearinghouses. Added to this survey is the word 'web' to emphasize that the required information was mainly collected on the Web. The Internet is an excellent means to gather regularly the needed information quickly and objectively, because of the easy access of the clearinghouse sites.

The survey was conducted systematically and periodically (April 2000, December 2000, April 2001, December 2001, April 2002, December 2002). The intention was to have a survey each half year because developments in information communication technology are difficult to monitor and keep up with. However, for practical reasons it was chosen to have a survey in April and December.

The methodology used in this survey consisted of the following two steps:

Step 1. Making an inventory of all existing national clearinghouses on the Internet.
Step 2. Measuring several characteristics to describe each clearinghouse.

The inventory (Step 1) was periodically compiled by extensive browsing of the Internet, reading related literature, and contacting experts and several webmasters. Clearinghouses were characterized (Step 2) based on the following criteria: ease of measurement, objective character and clear presentation of history, access network, people (suppliers, coordination, users), data, policy, and standards of the national clearinghouse environment. The following characteristics were periodically measured and recorded:

(1) Year of first implementation.
(2) Number of data suppliers.
(3) Monthly number of visitors.
(4) Number of web references (Alta Vista and Google).
(5) Languages used.
(6) Frequency of web updates.
(7) Level of (meta)data accessibility.
(8) Number of datasets.
(9) Most recently produced dataset.
(10) Use of maps for searching.
(11) Registration-only access.
(12) Metadata standard applied.

Almost all the above information was sourced from clearinghouse web pages. Additionally, in cases of uncertainty, language problems or missing data the webmaster/system administrator was contacted. The history of the clearinghouses is described by characteristic (1); people by (2–6); data by (7–9); the access network by (10); policy by (11); and standards by (12). In the following sections, some of the characteristics identified above will be explained and their developments will be discussed in greater depth.

Additionally, for analytical purposes, to improve the understanding of the development processes, extra information (especially about access network) was collected during January/February 2003 as follows:

(a) Status of national clearinghouse.
(b) Name of national clearinghouses.
(c) (De)centralized network architecture.
(d) Mechanisms for searching.
(e) Availability of view (web mapping) services.
(f) Type of coordination body.
(g) Percentage of periodically changed web addresses.
(h) Funding stability.

The access network is additionally described by characteristics (a–e); people by (f, g); and policy by (h). When referring to these characteristics below, the number or letter related to the characteristic is placed in parentheses.

4. Results

The presentation of the results is grouped using SDI component classification, which has been mentioned above (access network, people, data, policies and standards). First, the history of national clearinghouses is presented, followed by the results related to each of the SDI components. To present some of the developments in figures, both the average and median are used (figures 5, 6, 8 and 11). Due to the highly skewed distribution of some of the clearinghouse characteristics, the median is less sensitive to extremes than the average. In these cases, the median is more informative than the average. Some of the results are presented by region (this division in regions is derived from Dorling Kindersley 1997).

4.1. *History*

The history of national clearinghouses is characterized by the year of first implementation (1) on the Web. When implementing a clearinghouse, there are several activities that interact: design and implementation of discovery, transfer and access services, metadata preparation/validation/publication, legal/institutional environment creation and standardization definitions. The most tangible product derived from all these activities is the placement of a national clearinghouse on the Web.

From 1994, the number of national clearinghouses has been steadily increasing (figure 2). Now 67 countries have an implemented version on the Web. Additionally, it is known that 13 countries have projects for implementation (with all its related activities). Based on these developments, it can be expected that increasingly more clearinghouses will be established. Implementing national clearinghouses is a global activity; however, the variety in number between the different regions is considerable (table 1). For example, in Europe and America,

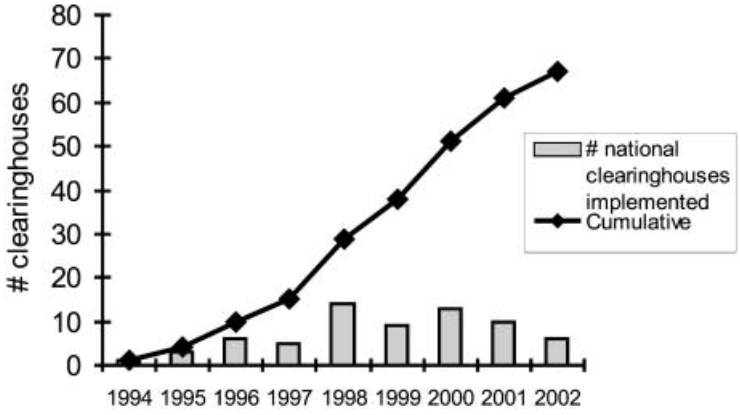

Figure 2. First year of national clearinghouse implementation: per year (columns) and cumulative (line).

Table 1. First year of national clearinghouse implementation (distributed per region).

First year of implementation	Total number of countries	Number of African countries	Number of Asia-Pacific countries	Number of European countries	Number of American countries
1994	1				1
1995	3			3	
1996	6	1	4	1	
1997	5		2	3	
1998	14	1	3	5	5
1999	9			5	4
2000	13		2	3	8
2001	10	1	1	3	5
2002	6	2	2	2	
1994–2002	67	5	14	25	23
2003/04?	13	5	3	3	2
No implementation	113	41	47	15	10

more than 50% of the countries have established a national clearinghouse, whereas in Africa and Asia-Pacific, this is less than 20%. The many project initiatives in Africa are promising.

Note that 113 countries did not conduct any initiative to build such a national facility. This may be due to several reasons, e.g. a country may not have appropriate network architecture or have institutional/legal bottlenecks preventing implementation (Crompvoets and Bregt 2003).

4.2. *Access network*

The access network component of an SDI is critical from a technical perspective to facilitate the use of data by people. This component seeks to facilitate access to relevant data sources and spatial information services by anyone, anywhere. The best example of an access network at national level is the national clearinghouse. The clearinghouse as access network is characterized by the status of national clearinghouse (a), by the name of a national clearinghouse (b), by (de)centralized network architecture (c), by mechanisms for searching (d), by use of maps for searching (10), and by the availability of view (web mapping) services (e). The differences in implementation status, network architectures, search mechanisms and view service provisions between the clearinghouses are broad.

According to the status of national clearinghouse implementation (a), three classes are distinguished: project, product-portal and clearinghouse. An implementation is considered a project when no clearinghouse is established on the Web where a project plan to establish one is already available. It is still in the stage of designing, preparing metadata, creating a legal/institutional environment or defining standards. For example, countries as Latvia, Poland, Botswana, Madagascar, Nigeria, Israel and India have set up projects for implementation. A national clearinghouse has the status of a product-portal when the spatial data are sourced from only one supplier. According to the clearinghouse definition, a clearinghouse should have spatial data from numerous sources. However, in several countries there is only one dominant national spatial data supplier (national (military) geographic institute). These countries are mainly located in South America and Europe. Most of these suppliers present their (meta)data as products. That is the reason why these types of national clearinghouses are called product-portals. This difference in the number of sources is the only difference between product-portals and clearinghouses. Examples of product-portals are: FÖMI-Products (Hungary, Institute of Geodesy, Cartography and Remote Sensing), Clearinghouse-SNIT (Chile, Military Geographic Institute), National Geospatial Data Clearinghouse (Peru, National Geographic Institute), and Geospatial catalogue (Venezuela, Geographic Institute of Venezuela Simon Bolivar). A national clearinghouse is classified as a clearinghouse when it completely fulfils all the criteria of the clearinghouse definition. The majority of the existing national clearinghouses have the status of clearinghouse (72%). Examples of classified clearinghouses are: MIDAS, Meta-Information DAtabase System (Czech Republic), Slovenian National Data Catalogue, Spatial Data Discovery Facility (South Africa), GeoConnections Discovery Portal (Canada), Geospatial Data Clearinghouse of Dominican Republic, Geographic Data Clearinghouse of El Salvador, and National Clearinghouse of Geographic Data (Uruguay).

Within the spatial community, various names have been assigned to this

national facility (b); examples are catalogue services (OpenGIS Consortium (OGC)), Spatial Data Directory (Australia) and Clearinghouse (USA). Although they have different names, the goals of discovering and accessing spatial data through the metadata properties they report are the same. As shown in figure 3, the most popular names are Clearinghouse and (Meta)data information system. Clearinghouse is especially used within the American continent.

A national clearinghouse could consist of a number of servers on the Internet that contain information about available data. A clearinghouse is an example of a client-server architecture (c). The server machines hold the metadata and services. The clients request metadata or services by visiting the server(s), usually through a web browser. A clearinghouse with a decentralized network architecture (c) means that the (meta)databases and services are distributed over numerous servers installed at different suppliers interconnected through a network with each server running autonomously. In total, nine decentralized national clearinghouses exist, mainly in countries of Anglo-Saxon origin (USA, UK, South Africa, Australia). However, the majority has implemented a centralized version wherein all the metadata and services are stored on servers installed at the main supplier or coordination body.

When searching on a clearinghouse, the user has the ability to choose different mechanisms for spatial data searching (d), like predefined search terms (hypertext links), Location (spatial search), Maps with Predefined boundaries (index maps), Free keyword search, Place name (gazetteer) and Production time. The most popular mechanisms are Predefined terms and Free keyword (figure 4). Searching by means of Predefined terms is mainly done by Name database (text index), theme, organization and geographical name. The use of digital maps when searching (10) is very popular. Maps can be used for locating an area of interest or by clicking on an area with predefined boundaries. These maps improve the data discovery. Nevertheless, the trend is that few national clearinghouses are using this mechanism. Fifteen national clearinghouses have made a link to the FGDC's search page by using the search-and-retrieve protocol known as ANSI Z39.50 or ISO 10163. Recently, OGC Catalog Service version 1.0 came on the market, which is an improved version to query, search and present search results to the user. It

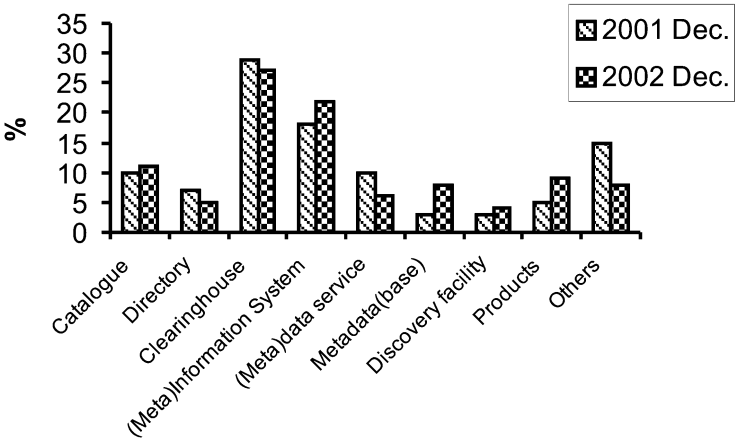

Figure 3. Distribution (%) of national clearinghouses based on naming.

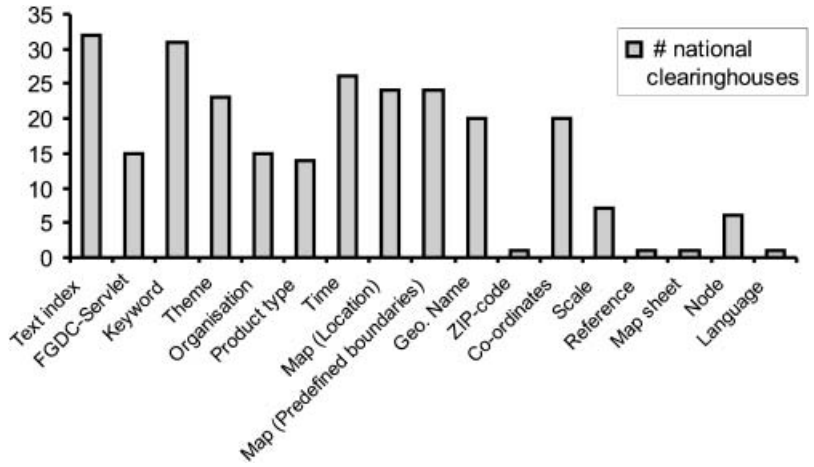

Figure 4. Distribution of national clearinghouses based on a mechanism for searching.

was recommended in *The SDI Cookbook* (Nebert 2001) that clearinghouses should use this new OGC Catalog Services Specification.

A relatively new facility within the domain of national clearinghouses is the standardized view services for documented data (INSPIRE Architecture and Standards Working Group 2002). This viewing of geographic information over the Internet is also referred to as web mapping (e). This service is a typical tool for second-generation SDIs. It includes the presentation of general-purpose maps to display locations and geographic backdrops, as well as sophisticated interactive and customizable mapping tools. Viewing is supported by simple queries. Related to the viewing is the requirement that the geographic information presented must be given a context, made easy understandable and of value to end-users. Understanding thematic geographic information coming from different sources requires standardization of the way in which the information is portrayed. The technology behind web mapping is aimed at portraying spatial information quickly and easily for most users, requiring only basic map reading skills. At this moment, 14 existing clearinghouses have already implemented services to view for documented data. They are mainly in Europe, North America and Asia. In Asia-Pacific especially this view service is very popular.

Other examples of services that are already implemented in some of national clearinghouses are download and e-commerce services. It is expected that these web service-based developments will dominate the field for the coming years.

4.3. *People*

Through increased use and awareness of spatial information, a dramatic growth has occurred in the user base. With the proliferation of online web mapping, and navigation/direction information, an increasing number of people are using GIS, this is obviously of importance in the development of an SDI to facilitate spatial data activities.

The people involved in a clearinghouse environment can be categorized into three groups: data suppliers, managers (service administrators) and end-users. The data suppliers represent the spatial data providers and developers. The behaviour of

people is characterized by the number of data suppliers (2), by the number of monthly visitors (3), by the number of web references (4), by the languages used (5), by the type of coordination body (f), by the frequency of web updates (6), and by the number of periodically changed web addresses (g).

Characteristic number of data suppliers (2) describes the variety and quantity of data providers and the spatial data developers of the national clearinghouse. The power of a clearinghouse is that several data suppliers can disseminate their products via this facility. The number of data suppliers was measured four times (December 2000, 2001, 2002, April 2002). As shown in figure 5, the average number of data suppliers participating in a clearinghouse is high (especially when compared with the median), however the variety between the clearinghouses is extremely high. For example, more than 1500 suppliers use the clearinghouses of Canada or USA to disseminate their data. This is in contrast with the more than 45 clearinghouses, which have less than 10 suppliers. The median is very low because of the high number of product-portals. The recent trend is that the average and median are decreasing. Based on this development, it seems that a national clearinghouse is losing its popularity to participate as a data supplier and to supply spatial data. From a spatial distribution context around the world, the very low number of data suppliers in South America is remarkable. The reason may be the dominant role of the leading mapping agencies.

Characteristic monthly number of visitors (3) indicates quantitatively the use of national clearinghouses to access spatial datasets by end-users. This number relates to the monthly number of visitors who have visited the homepage of the clearinghouse. It does not really present the usability of the clearinghouses for searching spatial data, because it does not identify the behaviour of the users within the clearinghouse and the number of different visitors. This characteristic is measured six times. The numbers relate to the month just before the measurement. This is the reason that March and November are presented (figure 6). For November 2002, the average number of visits exceeds 5000 visitors (however, the median is just above 1000). Note that the difference in visiting numbers between the clearinghouses is high. The most visited are those of the USA, Portugal, Finland,

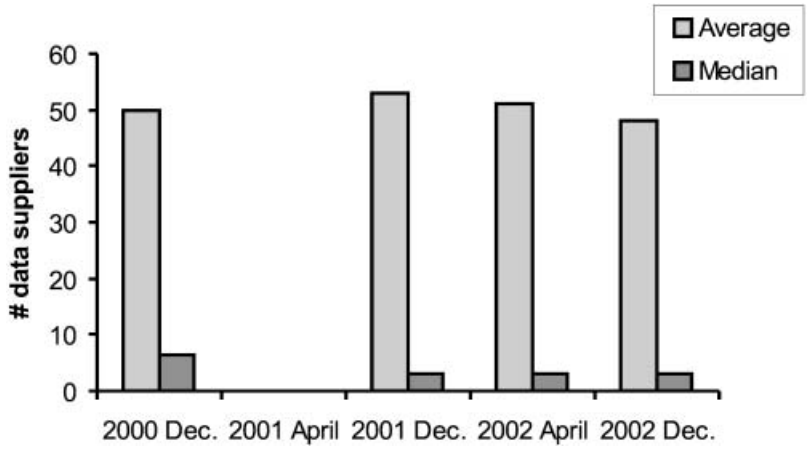

Figure 5. Number of data suppliers during time (average and median) Due to practical reasons, this characteristic was not measured in April 2000 or April 2001.

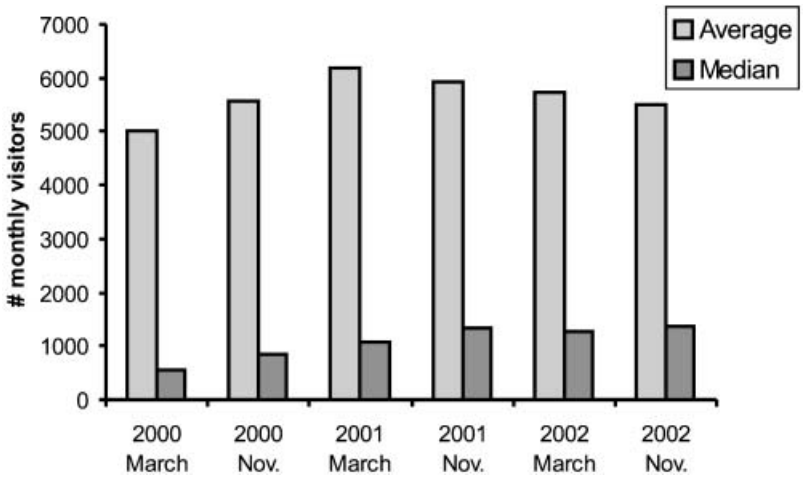

Figure 6. Number of monthly visitors during time (average and median).

Canada and Slovenia. In general, the highest numbers of visitors are found in Europe and North America. The recent development is that the numbers are stabilizing and not increasing. This could be an indication that the clearinghouse is losing its popularity to access spatial data.

Based on the gathered data, it seems that the implementation of web mapping facilities within the national clearinghouse environment increases the number of visitors. The average and median of the clearinghouses with web mapping are much higher than those that have not have such mapping (table 2). Therefore, web-mapping facilities could increase use. However, an important limitation of web mapping is the costs of implementation: €150 000 summed with €50 000–100 000 for each participating organization (INSPIRE Architecture and Standards Working Group 2002).

Another aspect that could increase the use of a national clearinghouse is the number of suppliers. This is based on the correlation coefficient (r) between the number of suppliers and the monthly visitors of December 2002: 0.73.

The characteristic number of web references (4) can be interpreted as a means to measure the popularity (use) of the national clearinghouse site within the Internet network. Used is the 'LinkPopularity.com, Free Link Popularity Service ©' (http://www.linkpopularity.com) (The PC Edge, Inc.), which measures the number of links to the homepage of the national clearinghouse that can be checked by the following search engines: AltaVista and Google. A well-linked popular web site can dramatically increase traffic to the specific web site. The link popularity of national clearinghouse is high, which means that they are an excellent source of consistent

Table 2. Impact of web mapping facilities on the number of monthly visitors (data between parentheses are the number of measured national clearinghouses).

Web mapping facilities	Average number of visitors	Median number of visitors
Yes (10)	13 324	5000
No (22)	1750	1280

and targeted web traffic. This characteristic is measured six times. The differences in numbers between the national clearinghouses are huge. The national clearinghouses with the highest number of web references are: Finland, South Africa, Australia, Canada, the USA and Colombia. Compared with other regions, the national clearinghouses of Africa have much lower numbers than the other regions. Since April 2002, Google has generally a higher number of web references than AltaVista. The correlation coefficient (r) of 0.71 between the number of web references (Google) and the number of monthly visitors, and $r = 0.75$ between the number of web references (Google) and the number of data suppliers show that the number of web references is an appropriate indicator of the use of national clearinghouses. The development is that both numbers of web references on AltaVista and Google are decreasing. The number of web references searched by AltaVista is already decreasing since April 2001 and the one searched by Google since April 2002. This is another indication that the national clearinghouses are losing their popularity.

Characteristic languages (5) refers to the language used at the 'search' page of the national clearinghouse. It indicates the ease for searching, the number and diversity of end-users able to access data, because of their familiarity and knowledge of given language. The percentage of clearinghouses in which data can be searched using the English language is slightly increasing. In December 2002, 60% of the clearinghouses have search facilities written in English. The percentages of 'Spanish' clearinghouses are stabilizing (around the 25%) and the ones of the multilingual clearinghouses are increasing. This means that people capable of understanding English have access to more spatial data. However, the metadata are mainly written in one language, mostly in one of a country's official languages.

The organization that provides the national clearinghouses as a service to society is characterized by the type of coordination body (f). It is the intermediary between the data users and the suppliers for the clearinghouse. It facilitates the integrity of access to the required data by ensuring system technical services as well as the administrative, data security and financial services necessary to broker between data suppliers and data users within the information policies governing the SDI. The main coordination of the national clearinghouses is mainly in the hands of the national mapping agencies (figure 7). In addition, the environmental agencies are of relatively high importance. This coordination characteristic has already been measured twice (December 2001, 2002). Additionally, a prediction for 2003 is made based on the existing information of projects for implementation. The relative trends (%) are generally very stable. The percentages related to national mapping and environmental agencies are slightly increasing, meanwhile the percentages related to cadastre, geological services, national councils for geo-information and commercial companies are slightly decreasing. The contribution of environmental agencies is particularly remarkable. It seems that environmental policy triggers focus on the need for SDI around the world.

Characteristic frequency of web updates (6) refers to the management in the national clearinghouse. It is the duration (days) between the day of the last web update and the date of measurement. High numbers of days refers to a low frequency of web update. One indication of a well-managed clearinghouse could be seen by the high frequency of updated information. It does not directly refer to the updates of the data itself, but to the updates of the clearinghouse web site. This characteristic is measured six times (figure 8). For consistency, it was measured each

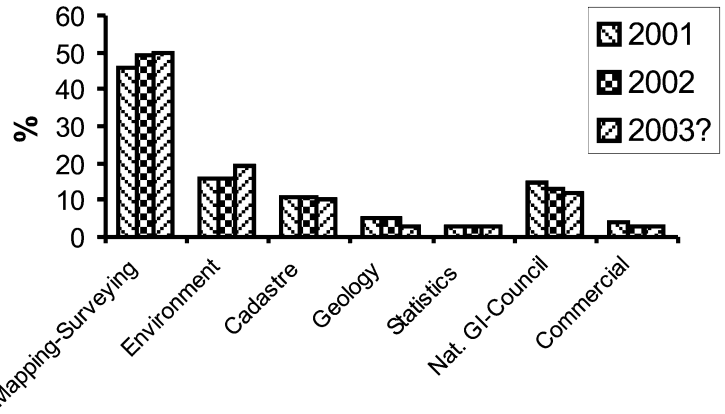

Figure 7. Distribution (%) of national clearinghouses based on the type of coordination body.

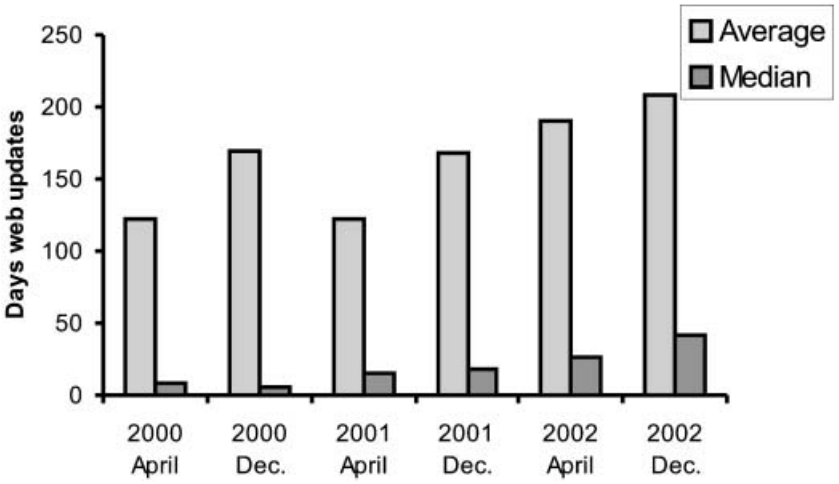

Figure 8. Frequency of web updates during time (average and median).

time on Fridays in the first week of April and December. The average number of days from the last update is high for the whole population of clearinghouses due to instances of poor management (with some updates exceeding 1 year). However, the median is low. The variation between clearinghouses is high as, alongside the poorer managed clearinghouse, numerous excellently managed facilities operate (update within 1 day). The update frequency is generally high in South America and low in North America and Africa. The development is an increase of the duration of the days of web updates, and so a lower frequency of these updates. The median shows an increase in trend. This could relate to a decrease of interest by clearinghouse managers.

Another characteristic to express management of national clearinghouses is by percentage of periodically changed web addresses (g). This refers to the change of URL address of the homepage of the same clearinghouse site during the period between the two times of measurements. This change is measured for five periods.

During period April–December 2002, 17% of all existing national clearinghouse in April 2002 changed their address in another one (figure 9). Most of the changes were in Europe. The development is an increase of the percentage of periodically changed web address. This dynamism could be an indication that the clearinghouse managers are struggling to create the right (technological) environment.

4.4. *Data*

Interoperability is a key consideration of both the standards and data component of an SDI. Data within an SDI should be compatible in terms of format, reference system, projection, resolution and quality. Data are described by the following characteristics: the level of (meta)data accessibility (7), the number of spatial (meta)datasets (8) and the most recently produced dataset (10). The difference in quantitative and qualitative content of accessible data between different clearinghouses is very high.

Characteristic level of (meta)data accessibility describes the presentation of the data content within national clearinghouses. In most cases clearinghouses provide access to standardized metadata. However, in a few cases these metadata are not standardized. In other cases, the user has the ability to access the data directly by means of its metadata. Delivery of data over the Internet can be realized in various ways. Some clearinghouses transmit data via e-mail; others serve the data through what OGC calls a Web Feature Server. Four classes are distinguished: prototype, non-standardized metadata, standardized metadata and data (+standardized metadata). Prototype refers to the level when final metadata security checks have to be arranged. Data (+standardized metadata) refers to direct access to data through the clearinghouse without contacting the producer. In a spatial context, Asia-Pacific has many clearinghouses that allow the user an opportunity to download spatial data directly. This is in contrast with the American region. In a relative sense, the percentages of standardized metadata access over time are very stable and the percentages of data (+standardized metadata) access are only slightly increasing (figure 10). Once a clearinghouse is established, the level of accessibility is unlikely to be changed.

A special form of non-standardized metadata is a graphical presentation (e.g. jpeg or bitmap format) of a subset of described dataset. This alternative is partly

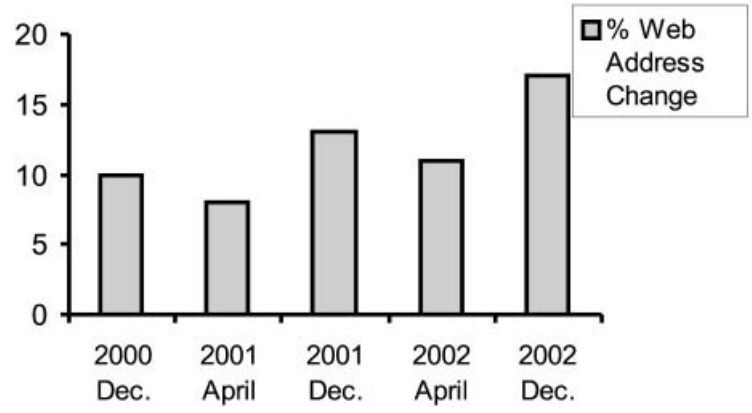

Figure 9. Percentages of periodically changed web addresses during time.

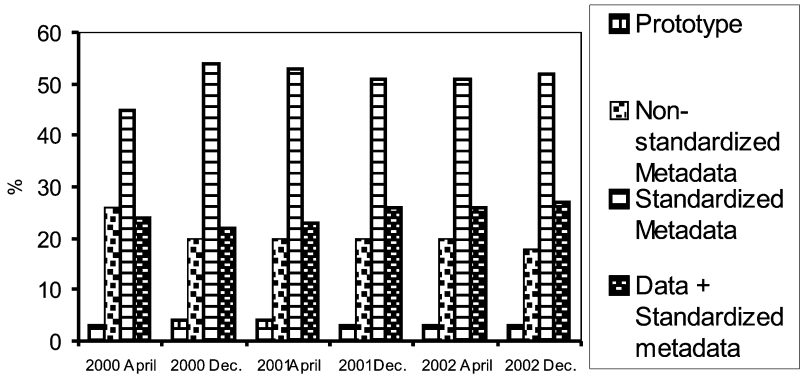

Figure 10. Percentages of the level of (meta)data accessibility during time.

based on the concept that 'a picture tells more than a thousand words'. It is particular popular in Europe. The recent development is a continuous increase of this type of metadata presentation.

A possible means to quantify the content of a national clearinghouse is characterized by the number of datasets. This number refers to the metadata records, where each describes one dataset. This characteristic does not represent the importance of the accessible datasets to the economic and social development of the country. This characteristic is measured five times. The variety in the number of datasets is enormous. For example, the US Federal clearinghouse allows the user access to more than $\pm 139\,000$ datasets, while the 25 European clearinghouses together give access to only $\pm 10\,000$ datasets. This is the reason that the average and median are so different (figure 11). It is remarkable that the average and median are decreasing over time. This trend could relate to the decreasing trend of the number of data suppliers. This observation is based on the very strong $r = 0.85$ between the number of suppliers and the number of datasets (December 2002). In the past, the total summed number of datasets of all the clearinghouses was steadily increasing. However, recently this trend has stopped and is stabilized around

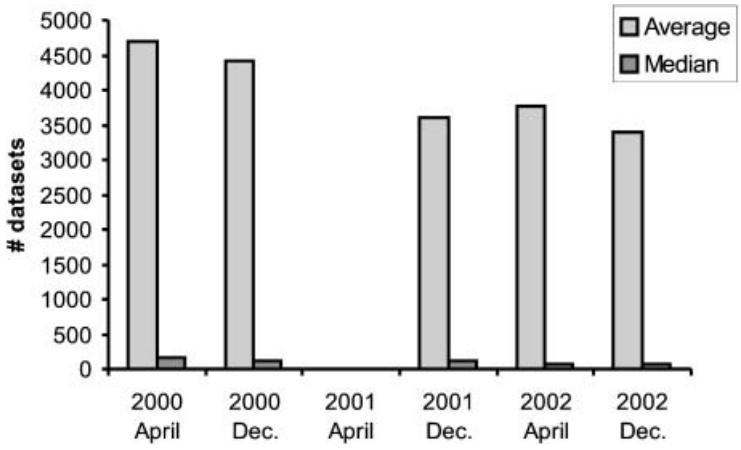

Figure 11. Number of datasets during time (average and median) Due to practical reasons, this characteristic was not measured in April 2001.

210 000. The trend of a decreasing number of monthly visitors could also partly relate to the decreasing number of datasets presented in the national clearinghouse. An r between the number of spatial datasets and the number of monthly visitors is 0.64.

The characteristic most recently produced dataset (9) describes the up-to-date nature of content and partly the management of content in the national clearinghouse. It is the duration (months) between the date of the most recently produced dataset described in the national clearinghouse and the date of measurement. It is measured six times. In general, the most recently produced datasets are in Europe and the least in North America and Asia-Pacific. The average time of most recently produced dataset is 33 months and the median is 20 months (December 2002). The recent development is a slight increase of the average and median duration. Therefore, the data of the national clearinghouses are becoming less up to date. This trend could have a negative impact on usage (r between the most recently produced dataset and the number of visitors is -0.45).

4.5. *Policy*

The policy and administrative component of the SDI definition is critical for the construction, maintenance, access and application of standards and datasets for SDI implementation. In general, policies and guidelines are required for SDI that incorporate: spatial data access and pricing; funding, spatial data transfer; custodianship; metadata; and standards. SDI component policy is only described by funding stability (h) and registration-only access (11).

Funds are mainly used to design and establish discovery, transfer and access services, metadata preparation/validation/publication, and legal/institutional environment creation. The most easily identified funding of clearinghouses comes from governmental agencies. Nevertheless, some signs suggest that other parties, mainly other public agencies, make enormously important contributions. Identification can be difficult because some are indirect, e.g. some are provided in kind through the time of staff already on payrolls, which are not properly attributed, or in returns to government through the tax system (Rhind 2000). The identifiable contribution to the national clearinghouse from the private sector is modest. An example that reflects partly this statement is that the government or other public agencies directly control 94% of the national clearinghouses. Funding of the national clearinghouses is mainly piecemeal (72%). Additionally, even a few clearinghouses exist that were never funded (6%)! A small number were continuously funded (22%). It is interesting that 25% of existing national clearinghouses were initially funded by foreign agencies such as the US Agency for International Development (USAID).

It seems that the stability of funding has a positive impact on people's use and management and of the quantity of the data of the national clearinghouses (table 3).

It was expected that personal registration in a clearinghouse could have a negative impact on end-users due to privacy. For this reason, registration-only access was introduced as a characteristic to be measured. Sometimes, before accessing the data, end-users have to register themselves by entering personal details. In 15% of all clearinghouses, the user should register him/herself by filling in 'registration template' (December 2002). The percentage of clearinghouses with registration obligations fluctuates around 15% over time. Based on acquired

Table 3. Impact of funding stability on the number of monthly visitors, the frequency of web updates, the number of suppliers and datasets (average and median).

Funding stability	Visitors, average	Visitors, median	Updates, average (days)	Updates, median days)	Suppliers, average	Suppliers, median	Datasets, average	Datasets, median
Stable	6487	5093	107	28	176	16.5	12 563	207
Number	5076	1322.5	239	68.5	15	2	467	42

information, it seems that this registration has no impact on the number of users and so it is no limitation for the users.

4.6. *Standards*

To ensure interoperability amongst the datasets and access mechanisms defined by an SDI, standards are essential. Standards can be applied at many different levels within an SDI. In terms of data, Australia's former national mapping organization, the Australian Land Information Group (AUSLIG 2001), identified that standards are required 'in reference systems, data models, data dictionaries, data quality, data transfer and metadata'. This component is represented by the application of a metadata standard (12) in the national clearinghouse. With the diverse sources from which spatial databases are built, it is extremely important to maintain information about the content, quality, source and lineage of the data. A number of standard organizations have developed, or are in the process of developing, standards for storing and maintaining metadata. The Federal Geographic Data Committee and the European Committee for Standardization (CEN/Technical Committee 287) have developed the main metadata standards. These meta-standards form the backbone of national clearinghouses. The FGDC metadata standard (Content Standard for Digital Geospatial Metadata, Version 2.0, 1998; FGDC 1998) is the most applied and distributed one around the world (26 clearinghouses, December 2002). Application of this standard is stabilizing at between 40 and 50% of all the national clearinghouses (figure 12). In Europe, CEN/287 Env 12657 (CEN/TC287 1996) is widely accepted. Recently, the International Organization of Standardization TC/211 has created the ISO19115 standard (ISO/

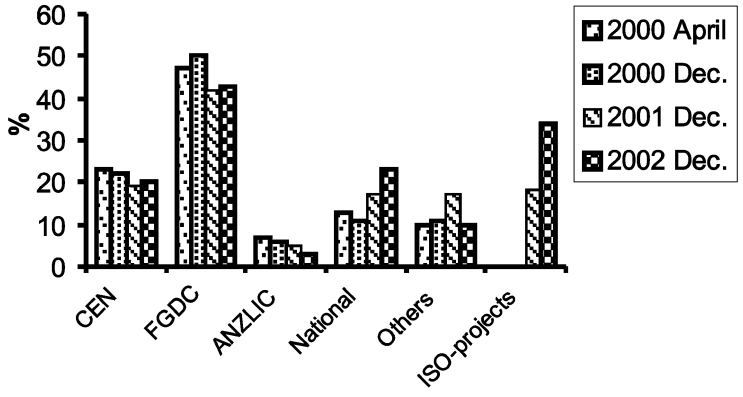

Figure 12. Distribution (%) of national clearinghouses based on the application of metadata standards.

TC-211 2001). Many countries have set up projects that deal with the harmonization of their metadata standard with the ISO standard 19115 for Geographic Information — Metadata in order to adopt the ISO standard as national standard (27 countries, December 2002). Many countries are creating their own profile of ISO 19115. That is the reason why the percentages of national metadata standards are increasing over time. The scope of the metadata standard ISO 19115 specifies that it defines metadata for services as well as data. ISO/TC 211 Project Team 19, which deals with ISO 19119 — Services, is developing more detailed service metadata. This ISO 19119 Services standard is at the Draft International Standard stage (Østensen 2001).

5. Discussion of results

The main objectives of the present paper are to analyse the worldwide developments, to describe these developments, to understand the reasoning behind these developments and to determine the critical factors for success. Each objective will be discussed in turn.

One of the survey's objectives was to analyse the worldwide developments. Through this Web survey, it was possible to examine the developments of all national clearinghouses on a worldwide scale. Using this approach, it was possible to gather the needed data quickly and objectively and on a regular-temporal basis. A traditional survey research described as a method for collecting information by asking a set of preformulated questions in a predetermined sequence in a structured questionnaire to individuals would not have been a very suitable approach to collect quickly, objectively and easily the required information. Of great importance was the back up of the numerous webmasters/system administrators in case the necessary information could not been collected directly from the Web. The response of these webmasters to the e-mailed questions was overwhelming. More than 80% of the e-mails sent were answered. A frustrating aspect of the followed approach was the high change of web addresses for the same national clearinghouse site.

A complementary study to this Web survey could be to analyse some case studies more deeply to determine the business requirements that have shaped the purpose, scope, design and implementation of the process and technical aspects of the national clearinghouses. An appreciation of these business requirements could improve the explanation of the trends in usage and in investment in the clearinghouse.

Another objective of the survey was to describe the developments. The number of national clearinghouses implemented is steadily increasing over time. In the near future, it is very likely that increasingly more countries will establish their national clearinghouse. From an implementation point of view, the introduction of national clearinghouse as a concept for the dissemination and access of spatial data can be considered as a success. This implementation of national clearinghouses is becoming almost a global activity. Not only is it rich countries that have built effective clearinghouses. Examples of relatively poor countries with suitable national clearinghouses are Chile, Colombia and Uruguay. However, currently, a decrease of interest in managing national clearinghouses is observed, which is a warning development. This observation is based on the decreasing number of data suppliers, frequency of web updates and the stabilizing number of datasets. These trends are almost all related to poor management of data providers and (especially)

clearinghouse managers. Another concerning trend is the decline in use. This development refers to the decreasing number of monthly visitors, suppliers and web references. Additionally, another negative trend is the lowering quantity and quality of data content. This development is based on the decrease of the number of datasets and the less up-to-date nature of the produced dataset. Of concern is also the way national clearinghouses are funded. Only a small number are funded continuously.

Although the differences in management, use, content and technology between the clearinghouses are high, the developments are very similar. After an initial peak, figures gradually enter a decline in the management, use and data content (only a few show a continuous increase in use and content).

In the future, many national clearinghouses are likely to give more access to spatial data and provide complementary services such as online mapping. These web services will change the functional capability of clearinghouses as well as the use of them to applications. At this moment, many clearinghouses are in kind of 'identity crises'. During the period of first-generation SDI, data were (the only) key driver for clearinghouse development. During the transition to second-generation SDIs, the use of data (data application) and the need of users is becoming the main driving force for national clearinghouses. These trends are reflected by the variety of search mechanism alternatives, the introduction of web services and the increase of multilingual clearinghouses.

The dynamic nature of SDI and clearinghouses is well reflected by the application of metadata standards to improve the interoperability amongst the datasets and access mechanisms. Many countries have set up projects to harmonize their metadata standards with the new ISO standard 19115.

Another objective of the survey was to understand the reasoning behind these developments. The reason that more national clearinghouses are implemented is that more countries realize the need and potential power of having one. Most of the existing clearinghouses are established in Europe, South East Asia, and North and South America. Nevertheless, numerous countries have still not shown any initiative to build one. There are several reasons for this. For example, a country may not have an appropriate network architecture or might have institutional, legal, cultural or economic bottlenecks.

The declining trends in use, management and content reflect the changing demands on clearinghouses. It seems that after a stage of orientation to clearinghouse implementations, SDI people are becoming dissatisfied with the existing clearinghouse functional capabilities. This dissatisfaction could be the consequence of the fact that the existing clearinghouses do not fit anymore the current expectations of the second-generation SDI people. This difference in demands relates to the dynamic nature of SDI, which has been highlighted by Rajabifard *et al.* (2002). Therefore, the implementations and concepts behind clearinghouses to share data between suppliers and data users are likely to be changed and resolved.

Another possible reason of these declining trends could be that the majority of clearinghouses are only funded in a piecemeal way. Management of clearinghouses is directly affected by funding. A consequence of bad management could be worse data content, which again could have a negative impact on use. These trends could also have a negative impact on the data suppliers who are no longer willing to

disseminate their data through the clearinghouse. This again could have a negative impact on use. These observations can be justified by the high correlation coefficients between the number of suppliers, the number of datasets and the monthly number of visitors.

As mentioned above, the focus on the need of the users is becoming a crucial aspect for implementation. At this moment, users have the right to expect more of these types of facilities. A point of concern is that clearinghouses are not always user friendly. It seems that the concepts of metadata and clearinghouses are too complicated; the terminology used is too discipline specific and too focused on the data alone. Therefore, it seems that clearinghouses do not fulfil the current demands of the users.

Several external developments are also impacting on the development of national clearinghouses and they will continue to influence the evolution of their application of this clearinghouse: expanding technologies, market-demand, changing business models, sustainable development, e-government and participatory democracy (Williamson *et al.* 2003). The introduction of web services within the clearinghouse environment is partly the technological answer to some of these developments.

The last objective was to determine the critical factors for success. Because of each country's unique historical, institutional, economic, legal, technical and cultural setting, no single best solution or recipe exists. However, the following are some indications of critical success factors:

- Be specific about the purpose of the clearinghouse under consideration. To be successful, there has to be a direct need to share data and services. When the context for implementation is missing, people will become frustrated to implement clearinghouses only out of fashion.
- Provide good communication channels for the community for sharing and using datasets instead of aiming only toward the linkage of available databases.
- Create stable funding. Stability of funding is needed to build a suitable framework that facilitates the management of information assets.
- Create trust and authority in the clearinghouse. Stability of funding could support this process.
- Create more user-friendly interfaces with less discipline-specific terminology.
- Introduce web services to clearinghouse. It is very likely that the software for web services will become cheaper in the future.
- Motivate data suppliers and web service providers to participate within the clearinghouse. The more data and web service providers, the more data and services are available. This improvement of the content will attract end-users.
- Motivate the clearinghouse managers to update their environment regularly.

6. Conclusions

Through the methodology followed, it was possible to assess the developments of all national clearinghouses on a worldwide scale. The strength of the web survey was the ease, speed and objectivity to measure the required data regularly.

The number of national clearinghouses is steadily increasing over time. It is expected that more countries will have implemented clearinghouses in the future.

From this perspective, the implementation of national clearinghouses can be considered a success.

This contrasts with the decline in the use, management and content of national clearinghouses. One of the main reasons for these concerning trends could be the dissatisfaction of the spatial data community with the functional capability of SDIs and clearinghouses. It seems that with the transition to the second-generation SDI, the demand on the efficiency of clearinghouses as well as how they are used is changing. Clearinghouses during the first-generation SDI were only data oriented, while in the second-generation SDI they are becoming more user and application oriented. Another reason for these declining trends could be that the majority of clearinghouses are only funded in a piecemeal way, which means that no suitable framework can be built to facilitate the management of information assets.

The main success factors that have a positive impact on the development of national clearinghouses are the inclusion of web services within clearinghouses, stable funding, the clarity of purpose of the clearinghouse, the provision of good communication channels, the creation of user-friendly interfaces with clear terminology, and trust and authority in the management environment. Addressing these factors will go a long way towards meeting the immediate needs of the current users. The full implementation is a major challenge for the future of the clearinghouse.

Another challenge is to keep spatial data suppliers, clearinghouse managers and end-users motivated for and informed about this mechanism. This is really needed when one considers their role in all the worldwide activities related to the implementation of national SDIs wherein national clearinghouses form the key component.

Based on the demands of the people to the second-generation SDI, the usability of spatial data and web services are the main research topics that have to be investigated to improve the functional capability of national clearinghouses.

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