A review of recent developments in national spatial data infrastructures (NSDI)

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Running Head: National Spatial Data Infrastructures (NSDI)

Abstract

Spatial Data Infrastructure (SDI) is the geographic data framework implementation of data, metadata, users and tools in terms of data infrastructure that are connected in interactive way to allow the flexibly and efficient use of the data. The SDI has different components which work together to make the whole system function properly. The components of the SDI have been defined by Federal Geographic Data Committee (FGDC): Framework, Metadata, Standard, Partnership and Geo-data. People were added to SDI because of their importance as the decision makers, and they make final decisions together with the people defined in the partnership component. In this article, basic definitions were explored for different components in terms of rules, organizations and needs; which can be quite useful for countries that are still in the early stage of creating a National Spatial Infrastructure design.

Keywords: NSDI, Data, Metadata, Clearinghouse, Standard, Partnership,Geo-data

I. Introduction

Spatial data infrastructure (SDI)has been employed in building an environment for stakeholders and decision makers which helps them reach their objectives at different levels(Politically or administratively) wherein they share their works with the help of technology. (Makanga and Smit, 2008; Cooper et al., 2012).Many countries have applied SDI due to its capability of facilitating easier interaction between different departments, and its ability to simplify the use of the data in different levels (organizational, provincial, regional, and global) (Klein and Muller 2012).Generally, the basic use of SDI is to make the rules of data sharing which helps in saving time and reduce the effort by different department or agencies (Hendriks et al., 2012). The avoidance of data duplication could be regarded as the most significant advantage of the use of SDI because the acquisition of data is only done once. In addition to the aforementioned property, SDI can help in establishing and maintaining data integration with other datasets (Boes et al., 2010). The elements of SDI controlling system cannot be managed centrally in many countries; therefore, it might be managed by the creator or owner. Computer networks and some other additional sources are the keys to successfully connect SDI tools. In order to operate effectively, complete information about the concept of NSDI components is required; this article therefore reviews the NSDI parameters in terms of its concept, application and implementation.

Spatial data infrastructure literature(SDI)

In the 1980s, various mapping agencies and national surveying felt the need to start the strategies for producing better access to standardized GI (Groot and McLaughlin, 2000; Williamson et al., 2003). The spatial data infrastructure (SDI) was made in the 1993 by the US National Research Council (Mapping Sciences Committee, 1993) with the aim of defining access to standardized GI access. SDI is defined as the entirety of the standards, technology, policies, human resources and related activities that are needed to acquire, process, distribute, use, maintain, and preserve spatial data between all government's levels, academia, and the private and non-profit sectors (http://www.fgdc.gov/nsdi/nsdi.html). This definition was made by the US Federal Geographic Data Committee (FGDC); however, Williamson et al., (2003) debated that SDI should be extended to be a cover environmental management, infrastructure support, economic development, and social stability in developed countries as well as the developing countries. There are various scales which operate on same basic principles for the SDI, these ranges fromsmall local departments to national and global scales. More than 100 SDI plans have been made through different countries at global, national, regional and local scales (Masser, 1998; Lachman et al., 2001; Craglia and Masser, 2002; GINIE, 2003; Lance 2003; Van and Kok, 2004).

National Spatial Data Infrastructure (NSDI)

The FGDC of the US ordained the implementation of the national SDI. The vision for NSDI was borne out of the necessity of making accurate and geospatial data facilely available to contribute globally, nationally and locally to environmental quality, economic growth and stability, and social progress (FGDC 1994). The US NSDI program was developed through three parallel parts: a group of standards for explaining, exchanging and accessing digital data; a clearinghouse network offering on-line access to metadata; and a group of framework datasets (e.g. administrative boundaries and rivers) that cover the whole country (Groot and McLaughlin 2000; Longley et al., 2001; Ryan et al., 2004). There are more than 100,000 organizations involved in SDI and GIS activities; however, it is not possible to call all the stakeholders for decision making, therefore, a structure should be made to inform all of them and then obtain their opinion in turn. This problem can be best tackled by creating hierarchical structures at the national, state and local levels as shown in figure 1(Masser et al., 2008).

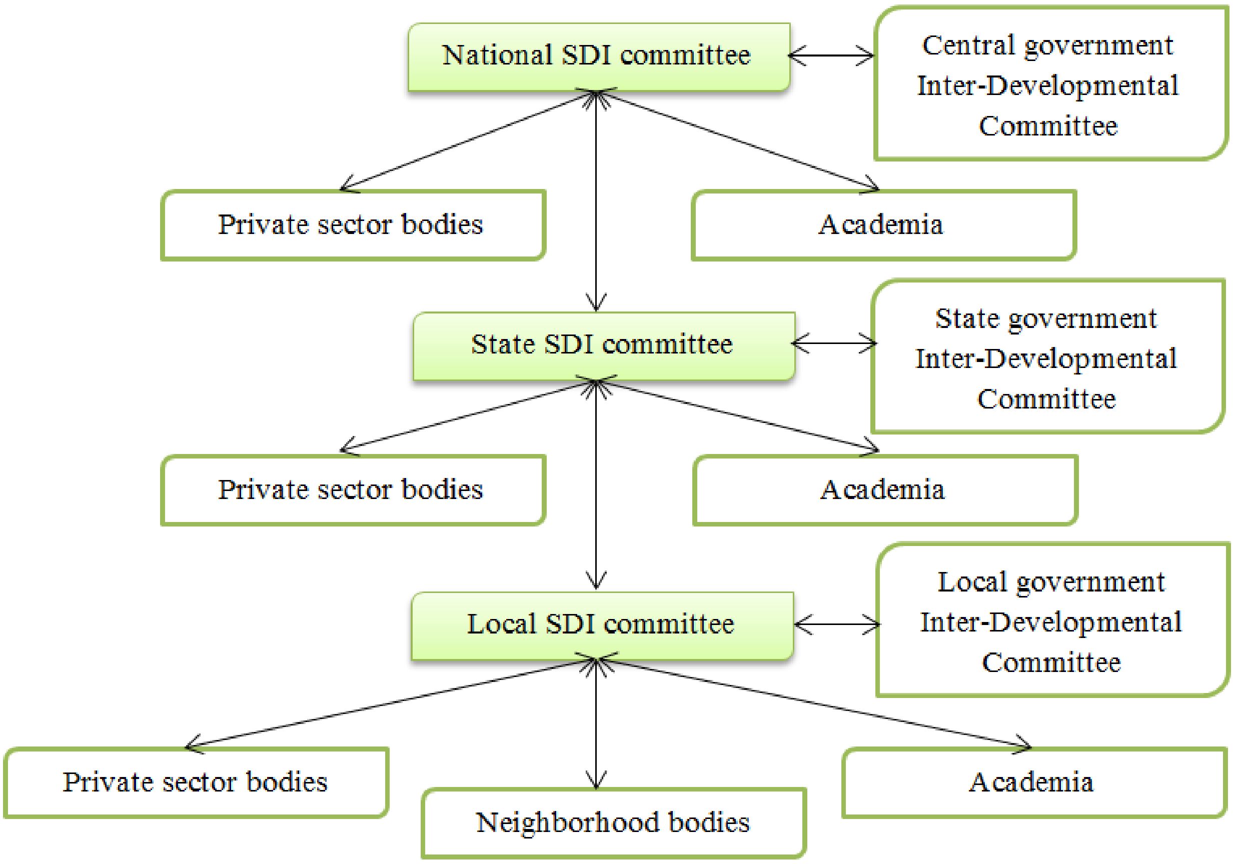

Figure 1: Hierarchical Relationships between National, State and Local Government Bodies in SDI Implementation. Adopted from (Masser*et al.*, 2008)

In this paper, we tried to review the Components of the NSDI and define the concepts in every parameter. Different parameters have different concepts which can be concerned to the conation's goal such as the framework orit can be related to the globe's vision such as standard. In addition, different Components can be discussed differently for instant, in the standard issue, the discussion about the different standard organization; however, in the clearinghouse issue, the comparism would be between different systems or different countries. The chosen components of NSDI are:(1) Framework (2) Metadata (3) Clearinghouse (4) Standard (5) Partnership and; (6) Geo-data.

Components and implementation

1. Framework

The agents of country, state and other organizations developed the concept of the framework under the sponsorship of Federal Geographic Data Committee (FGDC). The framework consists of three parts which are data, procedures and technology for developing and using the data (Data Content Standard), the third part can be the institutional relationships and business practices that support the environment.

1 -1 Data

Seven types for framework data of the geospatial applications were defined which are geodetic control, orthoimagery, elevation and bathymetry, transportation, hydrography, cadastral, and governmental units. Framework data were found to ease production and use of geographic data, reduce operating costs, and improve service and decision making. Firstly, the geospatial data are important for many projects; however, considerable period of time is needed to produce them and this is financially demanding. In many geospatial activities, the framework is incorporated. For instance the national map from the geological survey in U.S. includes framework concept in the development of the map as basis for geographic knowledge needed by the nation, and provides key content to the NSDI (Tulloch and Robinson, 2000).

1-2 Data Content Standard

The common data requirements are established by the Framework Data Content Standard (which is known as geographic Information Framework Data Content Standard) for the exchange of NSDI framework data. As described in the standard part, the main function of the standard is to reduce the cost of exchanging, collecting and maintaining framework data for the user and the creator. This can be done by establishing a group of data content elements and common means of explaining the data. The standard meets the requirement of the seven mentioned framework data themes and expands the data content. There are eight major parts in the framework standard seven of which them are associated to each of these data themes (geodetic control, orthoimagery, elevation and bathymetry, transportation, hydrography, cadastral, and governmental units) and the base standard which contains common information between two or more themes (Mishra and Koehler, 2006).

1 -3 Institutional relationships and business practices that support the environment

There are two parts in this concept which are the technical aspect and operation aspect. The technical aspect has the following features:(1) Feature-based data model (2) Permanent, unique feature identification codes (3) Reference to modern horizontal and vertical geodetic datum (4) Seamlessly integrated data for adjacent or overlapping geographic areas (5) Metadata. The operational aspect consists of: (1) Transactional changes (2) Access to past versions (3) Access to framework data through the Geospatial One Stop portal such as www.geodata.gov.

1 -4 Institutional Context

Innovative institutional arrangements ensure a robust and well-maintained framework. Ideally, the framework data for a geographic area will be developed, maintained, and integrated by the organizations that produce and make use of the data for that area. In addition, there is a need to ensure that the framework data can be integrated to support applications for different geographic areas.

II. Metadata

The key role of easing the accessibility of up-to-date data of the spatial information is performed by the metadata; furthermore, it is the most important part of the SDI function because it is the backbone of data sharing (Kalantari et al., 2010). The other term in the metadata is metadata harvesting which is an automated method for updating and collecting metadata from a wide variety of GIS metadata sources (Lynch, 2001). Metadata is most applicable when a user is interested in knowing how decisions have been made (Glover, 1997).

2-1 INSPIRE (Infrastructures for Spatial Information in the European Community) Metadata

In the INSPIRE, the following definitions were applied: Character String, Free text, Lineage, metadata, namespace, Quality and Resource (Shvaiko et al., 2010; Villa et al., 2012). Character string is one of the definitions which means ¡°the value domain of metadata elements expressed as a set of characters treated as a unit¡±. Lineage means the history of the dataset. Metadata element is defined as the unit of discrete of metadata, and namespace is defined as a collection of names, identified by a uniform resource identifier (URI) reference. Namespaces are used in extensible markup language (XML) documents as element names and attribute names. Quality is defined as ¡°the totality of characteristics of a product that bear on its ability to satisfy stated and implied needs¡±. Resource means ¡°an information resource that has a direct or indirect reference to a specific location or geographic area¡±. And finally, spatial data set means ¡°a collection of spatial data sets sharing the same product specification¡±. (http://inspire.jrc.ec.europa.eu/index.cfm/ pageid/101)

2-2ANZLIC (Australian) Metadata Profile

The ANZLIC metadata system was established for Australian and New Zealand and it meets the international standards. Diffused adoption of the ANZLIC system eases the interoperability between as well as within jurisdictions and agencies, internationally and within the region and it has consistent basis for the information transformation and the resources. The main elements in ANZLIC were established to contain 41 elements which were originally based on United States Federal Geographic Data Committee (FGDC).s content which covers the consideration the standards issue of FGDC as well as the draft standard ISO 19115 Geographic information metadata. The element of the ANZLIC metadata element are ANZLIC Identifier, Title, Custodian, Jurisdiction, Abstract, Search Word, Geographic Extent Name, GEN Category, GEN Custodial Jurisdiction, GEN Name, Geographic Extent Polygon, Geographic Bounding Box, North Bounding Latitude, South Bounding Latitude, East Bounding Longitude, West Bounding Longitude, Beginning date, Ending date, Progress, Maintenance and Update Frequency, Stored Data Format, Available Format Type, Access Constraint, Lineage, Positional Accuracy, Attribute Accuracy, Logical Consistency, Completeness, Contact Organization, Contact Position, Mail Address, Locality, State, Country, postcode, Telephone, Facsimile, Electronic Mail Address, Metadata Date, and Additional Metadata(Group, 2001).

III. Clearinghouse

Clearinghouse is an electronic facility for searching, viewing, transferring, ordering, advertising and/or disseminating spatial data from various sources by the internet (Al Shamsi et al., 2011). This facility usually can be from a number of servers connected with each other and contain information (metadata) about available digital data (Crompvoets et al., 2008). The facility provides integrated services and enhances exchange of spatial data between suppliers and users. It has different user-centric characteristics that address the perspective of users who are neither GIS experts nor familiar with the clearinghouses (Wirth et al., 2012).

The first clearinghouse was made by the Federal Geographic Data Committee (FGDC) in 1994: the National Geospatial Data Clearinghouse. It focused on facilitating efficient access to the massive quantity of spatial data (from federal agencies) and arranges its exchange. The target is to decrease the duplication (in the spatial data collection) and assist the other facilities where common helps exist (Rhind, 1999; FGDC, 2000; Crompvoets et al., 2004). A Clearinghouse Suitability Index was made to point out the measurement of the national clearinghouse quality and performance by using the 15 clearinghouse characteristics as explained by Crompvoets et al., 2004).

In 2004, a research was done by Crompvoets et al, with the purpose of analyzing the developments around the world, and to present the findings thereof. They used this information to figure out the causes behind these developments and to determine the stringent operations for success. As results, 15 characteristics were selected and questionnaire analysis was done as following: 1.Number of suppliers, 2.Monthly number of visitors, 3.Number of web references, 4.Languages used, 5. frequency of web updates, 6.Level of (metadata) accessibility, 7.Number of datasets, 8.Most recently produced dataset9.Decentralized network architecture. 10. Availability of view services; 11.Number of mechanisms (alternatives) for searching; 12.Use of maps for searching; 13.Registration-only access, 14.Funding continuity, and 15.Metadata-standard applied. The questions were established to give a weight for every factor to define its importance and find weather the

Clearinghouse succeeded or not. It was presumed that the selected factors represented the variables for determining the needs of the national clearinghouse to ease the spatial data/service discovery, accessibility, use and dissemination. Another survey was carried out in 2008 to estimate the development of the clearinghouse at the time by monitoring the development early in order to identify the efficiency of the national clearinghouses and comparing national clearinghouses to each other. Thirty eight countries worldwide have established National Spatial Data Infrastructure (NSDI) Clearinghouses on the internet as at April 2005. Assessing the development of different clearinghouse scales was achievable. In addition, a way of evaluating the strength of the web survey in terms of its ease, speed and objectivity for measuring the regularity of required data was also found (Crompvoets et al., 2008). The method for establishing the clearinghouse depends on technological, legal, economic, institutional, and cultural condition of the country. The national clearinghouse implementation may extremely vary between different countries (Crompvoets and Bregt, 2007).A national clearinghouse also differs from local, state, international, and global clearinghouses in that it is embedded in a national spatial data infrastructure.

3-1 The Development of a National Geospatial Data Clearinghouse in FGDC

The basic rules of the FGDC clearinghouse are as illustrated bellow (Clinton, 1994):

(a) Establishing a National Geospatial Data Clearinghouse.

The secretariats in the all the state, local and tribal levels establish an electronic National Geospatial Data Clearinghouse (..Clearinghouse..)for the NSDI. The clearinghouse should be appropriate and should meet the rules of the National Information Infrastructure in order to be permitted to successfully perform such integration.

(b) Standardized Documentation of Data.

All the geospatial data which are produced or collected in direct or indirect way should be under the standard and development of FGDC and those data should be electronically accessible to the Clearinghouse network.

(c) Public Access to Geospatial Data.

All the data should be available to the public, to the extent permitted by law, current policies, and relevant OMB circulars, including OMB Circular No.A130 (Management of Federal Information Resources), and any implementing bulletins.

(d) Agency Utilization of the Clearinghouse.

Internal procedures should be adopted to be sure that every agency has the ability to access the before that agency can be included in the federal funds to produce and collect the geospatial data. The agency must also be able to ascertain whether the data has been collected by other agencies or not.

(e) Funding

Every department should take into consideration the funding for the clearinghouse to cover the testing, standards development, and monitoring of the performance of the clearinghouse.

IV. Standard

The standard is one of the main branches on the NSDI without which data sharing cannot be achieved. The standard issue belongs not to the data only but includes the standard of spatial data contents, Standard of data exchange, Standard of meta-data and Standard of data services.

It is very important to have information about the data in terms of the quality, content, source and lineage. These information are collectively named metadata. Many standard organizations have been found (or are in the process of being developed) for storing and maintaining metadata. Many metadata standards organization have been employed by users. For instance, some of the famous standards are Federal Geographic Data Committee (FGDC 1995); ANZLIC; CSDGM; Dublin Core4 (DC); defacto standard such as FINDAR; and so on (Ramroop and Pascoe, 1999). The most affective one of these have been developed by the Federal Geographic Data Committee (FGDC, 1995) and the European Committee for Standardization (CEN/ 287 1996) (Crompvoets and Bregt, 2003). The standards of the metadata can be considered as the backbone of the data sharing concept because without a good standard for the metadata, the sharing of data will be baseless. The U. S. Federal Geographic Data Committee (FGDC) has Standard for Digital Geospatial Metadata which defines common geospatial metadata that allow prospective users to determine the following information about a geophysical data set: its availability, its fitness for an intended use, and the means of accessing and successfully transferring it.

In the standardization field, there are some popular international organizations work on the digital geographic data standard which they are ISO/TC211, Open GIS Consortium (OGC) and Internet-related bodies including the World Wide Web consortium (W3C) and the Internet Engineering Task Force (IETF)(Infrastructures, 2004; Bill, 2008;Hadi et al.,2012).

4-1 ISO/TC211

A number of formal models have been defined conceptually by the ISO TC 211 for the spatial data using Unified Modeling Language (UML) and Geographic Mark-up Language (GML) by the approach of geometry which was adopted from ISO spatial data model (Belussi et al., 2006). ¡°The standards might specify, geographic information, methods, tools and services for data management (including definition and description), acquiring, processing, analyzing, accessing, presenting and transferring such data in digital/electronic form between different users, systems and locations (Infrastructures, 2004).

4-2 ISO SQL/MM

The purpose of (SQL/Multi-Media) is to apply multimedia specific objects and their object packages (associated methods) by using the object-oriented features in SQL3 (ISO/IEC Project 1.21.3.4).The ISO SQL/MM is a multipart standard with the following parts:1-Framework, 2- Full-Text Part, 3-Spatial, 4- General Purpose Facilities,5-Still Image. Spatial is the third part of SQL/MM which has been proposed to provide database information to ease the spatial data management (Melton and Eisenberg, 2001).

4-3 Open GIS Consortium (OGC)

The open GIS community has achieved consensus on several families of interfaces, and some of these have been implemented in Off-The-Shelf software. All OGC consensus interface specifications carry a promise of community or commercial implementation based on their submission condition. The first phase of the initial OGC sponsored Web Mapping Test (WMT) bed initiative was successful in ¡°Web mapping¡± portrayal of spatial data. An XML-based encoding scheme, Geography Markup Language or (GML) for OGC Simple features was also an important output of the Test bed process. The publication of the OGC Web Feature Service (WFS) Specification in 2002 provided a solution for the standardized request and delivery of vector data (Infrastructures, 2004).

4-4.Spatial Data Transfer Standards

The Spatial Data Transfer Standard is a powerful way of transferring the various spatial data between non-similar computer systems with no information loss. Promoting and facilitating the digital spatial data between non-similar systems is the purpose of the SDTS. In addition, it keeps the information meaning and decrease the need for external information to be included. SDTS is made up of six parts, these are: Logical Specifications, Spatial Features, ISO 8211 Encoding, Topological Vector Profile, Raster Profile, and Point Profile.
The Author sees the need for different standards for different systems. As mentioned earlier, there are different systems and there is no one better than the other in particular because every system in different fields has its own benefits.

V. Partnership

"Partnerships and communication are the heart of SDI." (SDI Africa, 2010). NSDI cannot be established by the government alone because a lot of activities are done outside the government field. The private sector should be involved as an important part of the NSDI, as joint venture initiatives with data-owners, or involved in working the way ahead to deliver (Rukund, 2007).While the main target of the NSDI is to reduce duplication and allow sharing in terms of the spatial data collection, partnership has become one of the main way to achieve that target (Tosta, 1995). The main NSDI building tools are data partnerships, therefore, the local and state levels have been established through national associations with partnerships (e.g., the National State Geographic Information Council (NSGIC), the National Association of Counties (NACo), and the International City/County Management Association (ICMA)), and through contacts with all organizations of government levels. Also, partnership represents the people who take the last decision (the decision maker), therefore, the full essence of data accuracy, sharing, security, and access usually depends on the relationship between the people; good partnership enhance the quality of NSDI model at a big deal (Rajabifard, 2001;Hadi et al.,2012). The partnership includes Investment Funding, Human Resources Development, Public Awareness Raising, Scientific Research and International Cooperation (Mathew et al., 2002).

For successful partnership implementation, commitment must be from the top. The officials of the public should be

Prepared to take an active part for supporting the concept of Public private partnerships (PPP) by taking the leadership role in the given partnership development (Bo and Darija, 2010). The difficulty in the partnership lies in the challenge of choosing them because the lowest tender is not always the good choice for selecting a partner. In addition, the value of the partner remains critical to a successful partnership especially in long-term relationship (NCPPP, 2010).

In order to show the depth of the importance of PPP, it is better to go through their advantages. The advantages of PPP are financial effects, political support, and data democratization (Bo and Darija, 2010).

5.1 Financial effects

Understanding who the stakeholders are, what roles each member of the system plays, the time available, and the level of expertise and financial requirements are the important points for consideration for any developmental process. To have a successful financial return, many aspects of (PPP) must be taken in the consideration such as: maximizing the use of each sector strength, reducing the development risk, reducing public capital investment, mobilization of excess or underutilized assets, improvement on efficiencies and rate of completion, better environmental compliance, improvement of service to the community, improvement of cost effectiveness, sharing of resources, sharing/allocating of risks, and mutual rewards(Bo and Darija, 2010).

5.2 Political Support

The political support is brought by PPP as part of the partnership. Also a sustained political support is necessary for the implementation of NSDI, because the leadership of the government is the primary part of the SDI development.

5.3 Data democratization

One of the eventual targets of NSDI is the data democratization (Timothy 1999). Data sharing/exchange does not mean that every citizen has the ability to access data/information with or without a fee. That is due to the involvement of various levels of stakeholders, and data democratization such as federal, state and local governments in PPP. Obviously these participants should have democratic environment for the data user community rather than a bureaucratic environment which creates hurdles for data sharing, exchange and use (Bo and Darija, 2010).

The researchers found that partnership is one of the most important parts of the NSDI and without it, the system cannot work well. In addition, it was established that partnership should be considered even at global level referred to as GSDI (Global Standard Data Infrastructure). The people play crucial role in the success of SDI systems, however, many systems today still ignore this important aspect of the system.

VI. Geo-data

The information that explains and defines the characteristics of natural and the geographic locations or constructed features and boundaries on the earth is known as Geospatial data (Burrough et al., 1998). The collected information can be gathered from different sources such as remote sensing, mapping, and surveying technologies. In this definition, the statistical data might be included at the discretion of the collecting agency (Clinton, 1994). Trusted sources and hosts managed, contributed and administered portfolio of common services, data and application on a shared infrastructure for use by government agencies and partners to meet their mission needs and the broader needs of the Nation

6.1. Benefits of the Geospatial Platform

Improvement of the geospatial data for accessing and managing the resources can be done through shared leadership, business perspective, open government, transparency, accountability, and addressing administration policies (Lewis and Guan, 2011).

6.2. Geospatial Platform Features

The platform of the geospatial data has different types of features which can be listed as: Map Viewer, Trusted Federal Datasets, Multiple Base Maps, Collaborative Groups and Editable Layers (Lewis and Guan, 2011)
Geospatial data is widely deployed around the world in different systems and there is no doubt of its relevance and suitability for use in the SDI system. Geo-data was explained in this paper in order to show its concept and to highlight its importance in the SDI system.

VII. Conclusion

One of the most important use of spatial data is the development of a spatial data infrastructure (SDI). Many levels of SDI have been defined: local, national, regional, and global. However, the most developed one is at the national level which has been named National Spatial Data Infrastructure (NSDI). NSDI has many components, each with its own environment in terms of concept and implementation. All the components were appropriately defined and explained in different ways based on their applications, a typical case of this difference is evident when the fact that the standards are applied globally more than applied nationally is considered. Consequently, the discussion for the standard was discussed for different organizations. Other issues were discussed in the national region such as metadata which has been defined differently in different countries. It was found that the differences between the applications of the NSDI components does not necessarily mean it is bad or good; it depends on the needs and the conditions of the particular country in which it is being applied. Finally, the fact that some systems have reached an advanced SDI stage cannot be overlooked. Reliable systems developed using FGDC guidelines can be modified and adapted to suit the needs of any country. A good example of such adaptation and modification is the ANZLIC metadata which was originally based on FDGC system.

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