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A review of NSDI aspects (Components, Challenges, and Advantages)

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ABSTRACT
Spatial Data Infrastructure (SDI) is the implementation of infrastructure information as geographical data which is connected with users and tools in order to use spatial data flexibly and efficiently. This study represents SDI as a concept, components, functions, advantage, and disadvantage. It consists of clearing house, standards, and fundamental database as each organization specified its components as its requirements that usually been specified according to the environment that also causes a difference SDI definitions. People have been added as key component in SDI because they are the main factor in decision making. Clearing house provides linking among managers, users, and spatial data to achieve complementary service. SDI Institutional Framework has been divided into two major components; Policy and Institutional coordination. Policy refers to the approach of spatial data sharing among agencies. Coordination refers to collaborative efforts as it is the main factor in achieving a successful NSDI system. There are several challenges may face NSDI in most of nations such as accessibility and unviability data, standard, experts, and awareness scarcity. However, there are many benefits of NSDI; linking among multi-governments, monitoring programs, Harmonizes number sizes of spatial data, and partnership between public and private sectors.

Introduction
In order for decision makers and stakeholders to achieve their objectives at different levels (Political or administrative), Spatial Data Infrastructure (SDI) can be used to build an environment where they should cooperate, work together, and use technology. SDI have been recently used and applied in many countries around the world due to its importance in determining how the spatial data are being used by different levels (global, regional, national, provincial, and organizational). Basically, SDI allows sharing of the data. Hence, it reduces the time, effort, and resources that can be used by many agencies or departments which can be obtained by avoiding duplication of the data by acquiring them one time, in addition to maintaining and integrating the data with other datasets. In some countries, the key elements of SDI management system cannot be managed centrally; it managed by data owner or creator. Computer networks connect these tool and efforts with various sources.

What is SDI (Spatial Data Infrastructure)?

Spatial Data Infrastructure (SDI) is standards, human resources, and policies that need to collect, manage, and utilize geographical data efficiently. Many government agencies and researchers have defined SDI in various contexts because they understand it differently due to their different disciplines. Below are some of these definitions:

- (Clinton, 1994)defines a National Spatial Data Infrastructure as "the technology, policies, standards, and human resources necessary to acquire, process, store, distribute, and improve utilization of geospatial data".
- The Federal Geographic Data Committee (FGDC), the organization of US National Spatial Data Infrastructure, defines the US NSDI as a store to collect the geographic data nationwide in order to make these data available to a variety of users (FGDC, 1997).
- The Australian and New Zealand Land Information council (ANZLIC), The organization of coordinating and stewarding spatial information in Australia and New Zealand, defines the National Spatial Data Infrastructure as a model includes four substantial components: Institutional frame work which defines the administrative arrangement and the policy, Technical standards that sets the technical properties of the fundamental datasets, Fundamental data sets which are produced by institutional framework and complied by the technical standards, and the clearing house where the fundamental data sets can be accessed by the community(ANZLIC, 1998).

- Coleman and McLaughlin (1998) also defined the Global Spatial Data Infrastructure: "the policies, technologies, standards and human resources necessary for the effective collection, management, access, delivery and utilization of geospatial data in a global community".
- Dutch Council for Real Estate Informationdefines the National Geographic Information Infrastructure as sets of datasets, standards, technologies (software, hardware, and communications) , policy, and knowledge collected in order to provide users with required spatial data to implement a project (Rajabifard, 2001).

Manisa and Nkwae (2007)challenge the notion that many of SDI research papers tend to concentrate on an SDI as both a web-based technologies and GIS network used in data sharing or as a digital database by moving further in explaining the meaning of Infrastructure. They state that infrastructure means more than data collection, management, and conversion. They count some properties as follows: an infrastructure must be widely available, easy to use, flexible, multipurpose, and is the foundation for other actions as important characteristic distinguish an SDI from applications, projects, and technologies.

By examining the definitions, it is obvious there is no specific definition that has been used by all agencies and researchers. These variations are due to the differences in the goals, scopes, and responsibilities. Despite this most of the SDI initiatives would agree that NSDI is a cooperative effort provides an environment to the organizations and individuals who create and use spatial data by the assistance of technologies that ease the transformation and the use of these data.

NSDI Components:

There are some agencies and researchers have created their own NSDI components models based on their vision, goals, priorities, and the national requirements. For example, Federal Geographic Data Committee (FGDC) created an NSDI with six core components. These are: Clearing House/Portal, Partnerships, Standards, Metadata, GEOdata, and Framework (FGDC, 2005; Masser, 2002). In addition, Tosta (1995) suggested a model with four components: National Geospatial Data Clearinghouse, Geospatial Data Standards, Framework Data, and Partnership. Also, Australia New Zealand Land Information Council developed an NSDI model consists of four core components. These components are: Institutional Framework, Technical Standards, Fundamental Datasets, and Clearing House Network (Figure 1)(ANZLIC, 1998; Masser, 2002). Rajabifard and Williamson (2001),however, argued that the definition of the Global SDI which is mentioned by Coleman and McLaughlin (1998) considers the definition of ANZLIC as data-centric definition, because the relationship between the users and the suppliers of the spatial data is not taken into account although it is one of the keys in SDI development. In the same hand, due to the adoption of the same Australia SDI four components by the Permanent Committee on GIS Infrastructure for Asia and the Pacific (PCGIAP, 1998), it is considered as data-centricity. In order to consider the interaction between the people and the SDI and because people should be involved in the SDI framework as they are the key in making the decisions, Rajabifard and Williamson (2001) suggested that SDI consists of more than the four basic component that defined by ANZLIC. So, there is another component has to be added that is people.

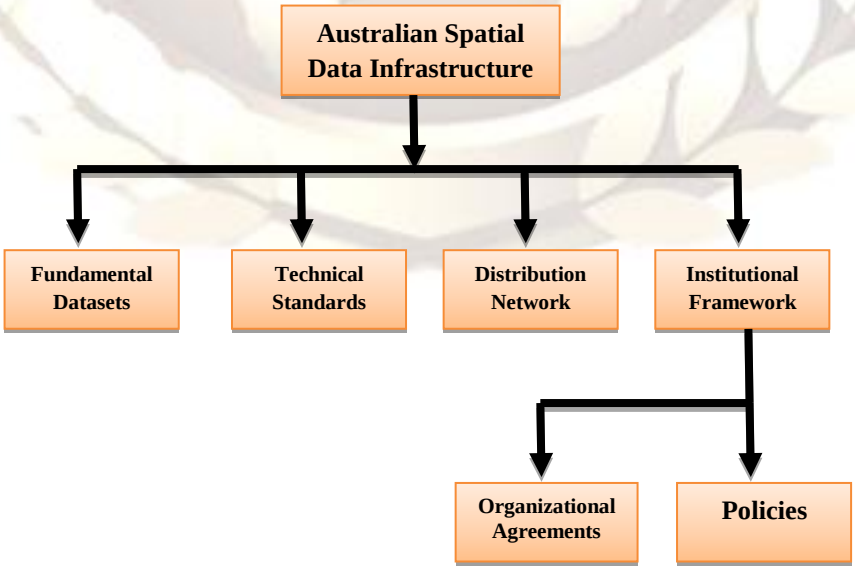

Figure 1 Components of Australian Spatial Data Infrastructure (Adapted from (Alhubail, 2004)**)**

By adding people, the components of the SDI become: people (including partnership), access network, policy, standards, and data. Crompvoets, (2006); Rajabifard, Feeney, and Williamson, (2002)stated that based on the difference incategories characteristics of their interaction with an SDI framework, the form of these categories could be changed. For example, data and people could be formed as one category based on the essential interaction between them. The second category consists of the technological parts: access network (e.g. Clearinghouse), policy, and standards. Moreover, the first category (people and data) is controlled by the second category (technological components). Furthermore, the dynamic nature of an SDI model is assigned to the change in the user requirements and the rapid advancement in technology. Therefore, important issues (policies, networks, and interoperability) should be involved in an integrated SDI in addition to spatial data, value-added service, and end-users (Figure 2).

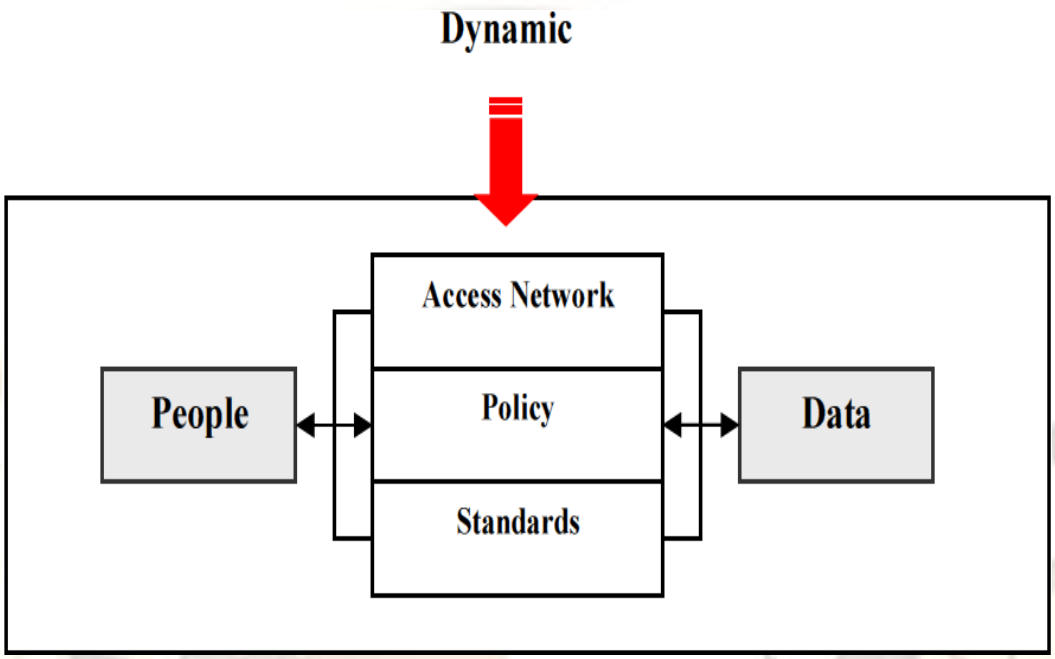

Figure 2 Relationship between SDI Components (adopted from (Rajabifard et al., 2002)

1- Data (Fundamental Datasets):

The main objective of this component is to build datasets that offer a unique geo-referenced environment in order to ensure an easy transformation of the data between agencies. Also, the existence of such datasets will reduce the duplication and reduce the efforts that should be introduced in collecting and managing the data (Tosta, 1995). For example, GeoConnection of Canada and US FGDC implemented a collaborative international product; that project was to create framework dataset for the regions on the borders between U.S and Canada. It was finished successfully with creation of dataset that compromises of nine layers and these layers have been made available for the public.

The U.S. National States Geographic Information Council (USNSGIC) and the U.S. Federal Geographic Data Committee (FGDC) made a survey for assessing the spatial data which created, stored, and maintained by regional, state, and local governments. The survey was conducted among 5000 data users around the whole U.S. This survey was to establish frameworkfrom these data and make them nationally available (Alhubail, 2004).

2- Standards

Any national spatial data infrastructure, in order to be successful in its aims, needs standard in many aspects: reference system, data dictionaries, data quality, data models, data transfer, and metadata(ANZLIC, 1998).

Data would come from different sources; every source creates the data based on its needs and requirements. Thus, the integration, in case of using SDI with clearinghouse for data sharing, would become not trivial due to the differences in the structure of the data. Therefore, offering a unique standard data set structure will serve many users and give the data the ability for being shared.

One of the good examples on using standards is FGDC metadata standard. This metadata was created by one of the US NSDI groups (working group) and then it was approved and used for any spatial data collected after early 1995 by all federal agencies. Furthermore, all agencies and public related to the standards created by FGDC review these standards before being adopted as a part of NSDI(Tosta, 1997a). Another example is the book named "National GIS Database Specifications and Data Dictionary– Topographic" was published by the center of GIS in Qatar. This book contains the specifications and data dictionaries. Also, GIS center in Qatar coordinated a project of collaboration between the government agencies that was ended with producing 16 volumes of data dictionaries. Finally, that ensures the data created by the agencies will be consistent which, hence, leads to increase the integrity in the national level(Tosta, 1997b).

There are two international standardization organizations work on the field of standardizing the digital geographic information. The first one is ISO/TC211 which is a standard technical committee constituted inside the International Organization for Standardization (ISO). Its work is similar to the second organization which is so-called Open GIS Consortium (OGC) but the latter is an international voluntary consensus. Both of them are responsible on creating international standards in geographic/ geomatics data(Bill, 2008).

3- Access Network (Clearinghouse)

Crompvoets (2006) defined a clearinghouse 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".

From the definition, it can be understood that Clearinghouse is a number of servers connected with each other and it stores spatial data with their metadata. These data can be accessed by the use of internet through some processes of searching and querying in metadata.Some of the researcher and agencies name it : access network (Rajabifard, 2001, 2002), some clearinghouse (Joep Crompvoets, 2006; FGDC, 1997; Tosta, 1995), and some Clearinghouse Network (ANZLIC, 1998; FGDC, 2009). Despite the variety in naming this component of the SDI, the general concept of these different names is similar.

A Clearinghouse implies linking of spatial data producer, managers, and users electronically in a distributed network(Clinton, 1994; J. Crompvoets, Bregt, Rajabifard, & Williamson, 2004; FGDC, 2009). By using clearinghouse, producers can know what data are existing, the status of these data, and how to access these data. Each dataset must be described in an electronic form (metadata) in order to be published by the producers. Then, the user can access the clearinghouse to find these data and to know who has what (Joep Crompvoets, 2006).

One of the most important thing is what was mentioned by (Shariff, Hamzah, Mahmud, Yusof, & Ali, 2011; Tosta, 1994)clearinghouse is not a centralized warehouse or database of spatial data, but on the contrary it is a distributed network. It is a place where the users can get cataloged and organized data not a place where the data are put and stored only. It is simply a network transfer the spatial data among all the users and producers.

4- People (Partnership):

All the components of an NSDI depend on a creative partnership or, in other word, the cooperation between the people that are involved in a process of NSDI. Also, Relationships are built by an NSDI to increase the ability of sharing information, developing, and maintaining standard datasets in a spatial data community (Tosta, 1995).

Moreover, all the decisions are made by people; all these decision need data to be made in the right way; the data cannot be exist without people. Therefore, by bearing in mind the meaning of data accuracy, sharing, security, and access are mostly based on the people relationship; good partnership increases the performance of any NSDI model at a big deal(Rajabifard, 2001).

Partnerships could be short term in order to address particular needs and requirements and continually developing. Also, many partnerships depend on cyberspace or on the internet to be linked more than the classical methods such as delivery-of-goods and person-in-your-office models (Tosta, 1995).

5- Institutional Frameworks (Policy):

Policy and administrative arrangement that ate utilized to create, maintain, access, and provide standards and datasets are defined by institutional framework (ANZLIC, 1998). Therefore, it can be divided into two major components that have different aspect. These components are: Policy and institutional structure or can be named institutional coordination.

Policy, Pricing, Copyright

One of the biggest challenges of the spatial data that are used by different agencies and sectors is the policy. So, the inconsistent policy would great a problem in sharing the data as many agencies have their own pricing mechanisms and policies. A conflict will probably happen in the policies through the process of sharing the data

between these agencies. Therefore, a policy with any SDI initiative is important to facilitate the access to the data by all the users and to organize the sharing procedure and the agencies tasks.

In U.S., the Office of Management and Budget issued the policy of the NSDI by the Circular A-16. This circular gives the directions of producing, maintaining, and using spatial data to federal agencies and provides great enhancements in the use of these spatial data and the coordination. Also, the Federal Geographic Data Committee (FGDC) is established by this circular in addition to a coordinated approach used to develop the NSDI electronically(OMB, 2002). Furthermore, In Qatar, there is no law that is special for protecting the data except the general copyright law, but in the same time Qatar GIS center has the authority to regulate the participation of agencies that are members in the national GIS program in case of any of these agencies violate the standards, methods, and procedures of implementing GIS project(Qatar, 1999).

In terms of pricing, many countries offer the data free of charge or some charge only the cost of transferring data or the media that used to copy the data. For example, Qatar GIS center collects a nominal charge for public user while the member agencies in the national GIS program use the data free of cost (Qatar, 1999). Also, FGDC offers the data free of cost for the agencies involved in NSDI and the public. As Tosta (1995) stated:

"Agencies should set use charges for data products at a level sufficient to recover the cost of dissemination but no higher. They also should exclude from the calculation of the charges costs associated with the original collection and processing of the data"

Institutional Structure/Coordination:

National Spatial Data Infrastructure is based on the cooperation as many agencies define it as collaborative efforts. Coordination is a mainstay of a successful NSDI. Also, as mentioned earlier, sharing data among agencies through some policies would increase the performance of an NSDI. These pillars of an NSDI, in order to be achieved, should be implemented in an excellent structured institution. The structure of an NSDI institution ensures the spatial data transfer to be smooth, policies to be well imposed, cooperation to be made by all involved parts, and coordination to be in high level which prevents the duplication of efforts such as utilized in data acquisition.

Coordination is the most important part in developing an NSDI. Craglia, Annoni, Smith, and Smits(2002) state that countries such as Spain, Belgium, and Austria have the least developed national spatial data infrastructure because they have, at the national level, the weakest coordination. While, these countries have a good examples of regional SDI due to an excellent developed mechanism of coordinating in regional level. On the other hand, U.S and the Nordic states have the most developed NSDI because their initiatives are controlled by strong multi-agency coordinating framework.

NSDI Challenges

Since the first establishment of NSDI in U.S in 1994, NSDI has faced many challenges and constraints almost in every NSDI initiative. Therefore, it is important to study these challenges that happened around the world in order to avoid or overcome them before facing difficulties in implementing an NSDI. There are some of the challenges that could be similar in most of the nations. These are(Alhubail, 2004; Arshad & Hanifah, 2010; GINIE, 2004; Manisa & Nkwae, 2007; Minh, 2009; Sen, Somavarapu, Sarda, & Sivakumar, 2006):

- **Accessibilityof the data:**
  When any government agency or department collects data, they feel this data is their own and no one has the authority to own them. By this, they forget the benefit of giving this data as they may need some data that are collected by others instead of collecting them again.

- **Availability of digital data:**
  One of the bases in NSDI implementation is sharing the data and this can be difficult with non-digital data. Also, sharing has become easier with the advancement in the technology which can be done by using the internet.
- **Need of Coordination (Institutional arrangements):**
  Avoiding the duplication is one of the most important advantages of NSDI. And this advantage cannot be achieved with the lack of coordination and without good arrangements among agencies, particularly among agencies that receive the money from the same resource (i.e. government). The data may be collected by one of the agencies and as a result of absence of the coordination the same data collected again which duplicates the efforts and the money.

- **Incompatibility of data (lack of standards):**
  Sharing the data is affected greatly by the lack of data sets standards. Collected data can be classified and organized in different ways, especially when using GIS databases, based on each agency needs and requirements. Hence, these data cannot be integrated in order to be shared with other agencies.

- **Lack of experts (knowledge and skills):**
  NSDI system design and management needs experience and knowledge in order to put the concept of the institutions structure and policy in a network and database. On other words, there is a lack of experts in GIS and IT fields.

- **Absence of technology infrastructure:**
  In many countries, the problem of deficiency of the technology such the high speed internet, fully constituted WAN and LAN is still present. Sharing the data is affected by this issue as agencies cannot give and take the data easily.

- **Lack of Awareness:**
  Many non-government agencies, public, and private sectors still have no information on GIS and SDI. These people are not cooperating due to their unawareness of the benefits of disseminating information to the public and the importance of sharing the data.

- **Funding limitation:**
  Many organizations suffer from the lack of funding in many spatial projects because these projects have big size data which need high processing equipment in addition to big size storage which are too expensive. Also, government agencies have some constraints in funding as they may need to show results to get the required fund. In addition, as mentioned above, the lack of organization may duplicate the money that is spent on different projects for the same area.

- **Availability of Metadata:**
  The presence of metadata facilitates the ability of the users to reach its need rapidly and easily. Therefore, collection of a big size of data without metadata describe them would be like a mess. Also, the access to the required data would be time consuming if there is a probability to find these data.

- **Need of Legal aspects:**
  NSDI is not only consisting of technical aspect. It is supported by policies and laws, and some of the agencies consider policies as the most important component of NSDI. Policies of many organizations are not suitable for digital data. This usually happens through the process of moving from the use of paper maps to digital data which can be transferred by the networks (internet, intranet). When policies are to manage paper maps and traditional approaches, and they are no longer can be used for digital forms. Also, another issue is the lack of the policies of the multi-field and multi-agency cooperation.

- **Difference in languages:**
  The provision of a platform with multilingualsupport is important and is not a trivial issue. Many nations consist of more than one language. Thus, data may be entered in a language which is different from some of the users. Therefore, there would be difficulties in searching, querying, and analysing the data.

- **Weak Cooperation:**
  The main pillar of NSDI is Cooperation. The more cooperation in an NSDI initiative the more successful will be. Some of NSDI projects may implemented in a multi-stakeholder environment where the partnership has to be enough strong to push the project to the success. A number of NSDI projects experience uncooperative organizations which can affect all the aspects of an NSDI significantly.

- **Long Term Benefits:**
  Some of the stakeholders resist an NSDI project in case of there is no evidence on short or medium term benefits because NSDI projects need some time in order to show result or benefits.

NSDI advantages

Throughout the world, many NSDI initiatives have been established and many researchers have studied it from many aspects (Components, Challenges, Advantages, implementation approaches…etc.). In any of these NSDI, there are many challenges must be overcome to move on looking for the success. Therefore, the benefit of NSDI should be strong enough to motivate any government in different levels to start such project. Some of NSDI advantages have been summarized as follow(CGDI, 2003; Cetl & Tomi, 2009; Manisa & Nkwae, 2007; Martirano, Bonazountas, & Gagliardi, 2009; Shariff et al., 2011; The Land Information Council Of Jamaica, 2007)**:**

- Guarantees the availability of the data to the users from different agencies.
- Prevents the duplication in the spatial data by ensuring the data is collected one time.
- Removes the redundancy of the spatial data.
- Supports the economic development at different level: national, provincial, and local by providing platform has all needed maps by investors and private sectors, and promoting geospatial technology for tourism.
- Links multi-government country by using inter-jurisdictional and intra-jurisdictional linkages.
- Increases transparency of government and decision-making.
- Improves the cooperation among agencies and different departments.
- Creates and promotes the partnership between public and private sectors.
- Enhances managing natural and land resource in addition to the actions that affect community.
- Helps in providing the foundation in a consistent and cost-effective manner for monitoring programs (Environmental, Economic, and social changes).
- Harmonizes numerous sizes of spatial data.

Conclusion

Coinciding with the fast development of spatial data and the expansion in the use of digital spatial data, SDI has become in the last three decades an important spatial aspect. NSDI has taken the biggest place in this development in comparison with others levels of SDI (Local, Regional, and Global). In order to implement a successful NSDI in any country, there are many challenges which must be overcome before and through the implementation of such project, as these challenges have faced the developed and developing countries which they have carried out the same projects and most of these projects have been considered as successfully implemented NSDI. Also, a mile stone that should be understood by the people who is going to implement an NSDI (especially, Decision makers) is the advantages of the NSDI that will be obtained in a long term and not in a short term.

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