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SPATIAL DATA INFRASTRUCTURES: CONCEPT, SDI HIERARCHY AND FUTURE DIRECTIONS

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ABSTRACT

The world as we know it is changing. Economies world wide are undergoing a process of profound and continuing structural change, and the global village is becoming a reality driven by IT and communication technologies. With this in mind, many countries believe that they can benefit both economically and environmentally from better management of their spatial data assets by taking a perspective that starts at a local level and proceeds through state, national and regional levels to global level. This has resulted in the development of the Spatial Data Infrastructure (SDI) concept at these levels.

SDI is fundamentally about facilitation and coordination of the exchange and sharing of spatial data between stakeholders from different jurisdictional levels in the spatial data community. Understanding of its role and nature are important to the acceptance of the concept and its alignment with spatial industry objectives.

The aim of this paper is to present the nature and concept of spatial data infrastructures, including the SDI hierarchy, which have helped to build understanding about the importance of the relationships within different levels of SDIs to support the interactions and partnerships of the spatial data communities. Moreover, the paper will highlight the importance of sharing and understanding its special social system, followed by a discussion of the future direction of SDIs. It is argued that by better understanding the future direction of SDIs, any SDI development can gain support from a wider community of both government and non-government data users and providers.

INTRODUCTION

We live in an age of information, and geographic information is one of the most critical elements underpinning decision making for many disciplines. In this regard, many of the things that different organisations want to achieve together can only be achieved if good, consistent spatial data is available and readily accessible. This is especially important when planning for the future. Geographic data are still expensive and time consuming to produce. In recent years nations have made unprecedented investments in both information and the means to assemble, store, process, analyse, and disseminate it. Thousands of organisations and agencies (all levels of government, the private and non-profit sectors, and academia) throughout the world spend billions of dollars each year producing and using geographic data (FGDC 1997, Groot and McLaughlin 2000). This has been particularly enhanced by the rapid advancement in spatial data capture technologies, which has made the capture of digital spatial data a relatively quick and easy process. But, they still do not have the information they need to solve critical problems. There are several aspects to this problem:

- Most organisations need more data than they can afford;
- Organisations often need data outside their jurisdictions or operational areas. In addition, information needed to solve cross-jurisdictional problems is often unavailable; and
- Data collected by different organisations are often incompatible.

Under current circumstances governments of different nations, and organisations within each nation should reach agreement on what fundamental datasets are required to meet their common interests, to what standards they should be collected and maintained, and what the priorities are for their collection. This is because it is necessary to integrate a number of datasets that may have been produced by different agencies within different nations for specific purposes, to their own specifications and priorities, and with little regard to the needs of other users. This narrow focus, whilst understandable, leads to inefficiencies and duplication of effort. With this background, many countries believe they can benefit both economically and environmentally from better management of their spatial information by taking a perspective that starts at a local level and proceeds through state, national and regional levels to a global level. This has resulted in the development of the Spatial Data Infrastructure (SDI) concept at these levels.

To this end, this paper briefly reviews the nature and concept of SDI, including the components, which have helped to build understanding about the importance of an infrastructure to support the interactions of the spatial data community. It discusses the relationship between infrastructures and the business systems they support. Then it expands the concept of an SDI hierarchy and the role that each SDI level can play in sharing spatial data within different communities by highlighting the importance of the partnerships concept to support such sharing. Finally, the paper demonstrates the inter-relationships between human and technical aspects of information infrastructure, based on two models for SDI development.

SPATIAL DATA INFRASTRUCTURE

Spatial Data Infrastructure (SDI) is an initiative intended to create an environment in which all stakeholders can co-operate with each other and interact with technology, to better achieve their objectives at different political/administrative levels. SDIs have become very important in determining the way in which spatial data are used throughout an organisation, a nation, different regions and the world. In principle, they allow the sharing of data, which is extremely useful, as it enables users to save resources, time and effort when trying to acquire new datasets by avoiding duplication of expenses associated with generation and maintenance of data and their integration with other datasets. By reducing duplication and facilitating integration and development of new and innovative business applications, SDIs can produce significant human and resource savings and returns.

Current progress of SDI initiatives shows that SDI is understood differently by stakeholders from different disciplines. In this regard, researchers and various national government agencies have attempted to capture the nature of SDI in definitions produced in various contexts. For example:

- The Australian and New Zealand Land Information Council (ANZLIC 1998) defines a National SDI as comprising four core components: an institutional framework, technical standards, fundamental datasets, and clearinghouse networks. The institutional framework defines the policy and administrative arrangements for building, maintaining, accessing and applying the standards and datasets. The technical standards define the technical characteristics of the fundamental datasets. The fundamental datasets are produced within the institutional framework and fully comply with the technical standards. The clearinghouse network is the means by which the fundamental datasets are made accessible to the community, in accordance with policy determined within the institutional framework, and to agreed technical standards; or

- The Federal Geographic Data Committee (FGDC 1997) defines the United States' National SDI as an umbrella of policies, standards, and procedures under which organisations and technologies interact to foster more efficient use, management, and production of geospatial data. It further explains that SDIs consist of organisations and individuals that generate or use geospatial data and the technologies that facilitate use and transfer of geospatial data; or

- Dutch Council for Real Estate Information (Ravi) defines the Dutch National Geographic Information Infrastructure as a collection of policy, datasets, standards, technology (hardware, software and electronic communications) and knowledge providing a user with the geographic information needed to carry out a task (Masser 1998b).

Whilst these existing definitions provide a useful base for the understanding of different aspects of SDI, or SDI at a snapshot in time, the variety of descriptions have resulted in a fragmentation of the identities and nature of SDI, derived for the varied purposes of promotion, funding and support. Lack of a more holistic representation and understanding of SDI has limited the ability to adapt to its evolution in response to the technical and user environment.

In summary, an SDI is much more than data and goes far beyond surveying and mapping, it provides an environment within which organisations and/or nations interact with technologies to foster activities for using, managing and producing geographic data. Also, with the rapid improvement in spatial data collection and communications technologies, SDIs have become very important in the way the spatial data are used throughout a company, a governmental agency, a nation, throughout regions and even the world. They allow the sharing of data, which is extremely useful, as it enables spatial data users and producers to save their efforts when trying to acquire new datasets. Moreover, an SDI is seen as basic infrastructure, like roads, railways and electricity distribution, which supports sustainable development, and in particular economic development, environmental management and social stability. Importantly it must be users or business systems which drive the development of SDIs. In turn the business systems which rely on the infrastructure in turn become infrastructure for successive business systems. As a result a complex arrangement of partnerships develops as the SDI develops.

In this end, to realise the advantages of an SDI and to speed up its development, at least six key factors should be considered. These factors are:

- awareness of use of Geographic Information (GI) and SDIs;
- cooperation between the various stakeholders;
- involvement of the politicians concerned;
- knowledge about the type, location, quality and ownership of datasets;
- accessibility of datasets; and
- the successful widespread use of the datasets.

All stakeholders, including politicians and technical people, should be aware of the potential and advantages of GI and SDIs. The organisation responsible for an SDI initiative must help to raise this awareness. The development of an SDI is a matter of cooperation and partnerships between all stakeholders. The involvement of those politicians concerned with the SDI development is essential. The politicians' support provides legitimacy and encourages the necessary financial investment for the SDI development. Knowledge about the types of data, its location and quality is also required. It is also important to provide access to the data as the measure of success of the SDI will be the widespread use that is made of it and an appreciation by its users that it is providing the promised benefits which were the justification for establishing the SDI.

COMPONENTS OF AN SDI

After reviewing a number of definitions of SDI, including the three cited above, Coleman and McLaughlin (1998) define the Global SDI as encompassing 'the policies, technologies, standards and human resources necessary for the effective collection, management, access, delivery and utilisation of geospatial data in a global community'. In this context, they regard the ANZLIC definition of SDI as data-centric, not taking into consideration the interactions between the suppliers and users of spatial data which is a key driving force in SDI development. This data-centricity also applies to the Asia-Pacific SDI development by the Permanent Committee on GIS Infrastructure for Asia and the Pacific (PCGIAP 1998), which adopts the same four components as ANZLIC (ANZLIC 1996), applying them at a regional (multi-national) level. Based on these selected samples of definitions of an SDI, it is suggested that an SDI comprises not only the four basic components identified for the Australian SDI, but also an important additional component, namely, people. This component includes the spatial data users and suppliers and any value-adding agents in between, who interact to drive the development of the SDI. For this reason the formation of cross-jurisdictional partnerships have been the foundation of SDI initiatives supported to date.

People are the key to transaction processing and decision-making. All decisions require data and as data becomes more volatile human issues of data sharing, security, accuracy and access forge the need for more defined relationships between people and data. The rights, restrictions and responsibilities influencing the relationship of people to data become increasingly complex, through compelling and often competing issues of social, environmental and economic management. Facilitating the role of people and data in governance that appropriately supports decision-making and sustainable development objectives is central to the concept of SDI.

Viewing the core components of SDI as policy, access network, technical standards, people (including partnerships) and data, different categories can 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 network, policy and standards. The nature of the second category is very dynamic due to the rapidity with which technology develops and the need for mediation of rights, restrictions and responsibilities between people and data 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 dynamics of the whole SDI concept. According to Figure 1, anyone (data users through producers) wishing to access datasets must go through the technological components.

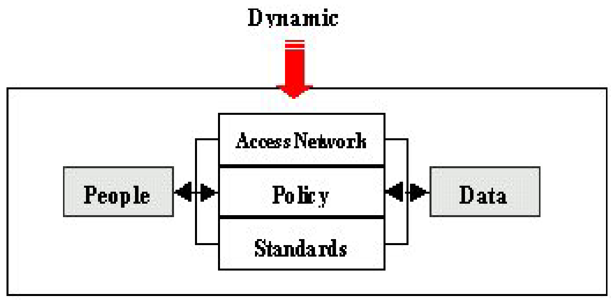

Figure 1: Nature and relations between SDI components

There are numerous approaches taken through varying SDI initiatives for the relationships defined between people, data and the initiative's objectives. One approach has been the development of strategic partnerships. The influence of the level of SDI and the focus for the technical components have an important influence on the approach taken for aligning components towards the development of SDIs.

CURRENT SDI INITIATIVES

National Level

With increasing frequency, countries throughout the world are developing SDI to better manage and utilise their spatial data assets. A number of publications document the various aspects of the development of national SDIs in recent years (Masser 1998a, Onsrud 1998). These countries are finding it also necessary to cooperate with other countries to develop regional and global (multinational) SDIs to assist in decision-making that has an important impact across national boundaries.

Masser (1998b) and Onsrud (1998) have identified some of the countries that have begun work on SDIs at this level. Some of these countries are Australia, Canada, China, Colombia, Denmark, Finland, France, Germany, Hungary, Italy, Indonesia, Japan, Malaysia, Netherlands, Portugal, Spain, Switzerland, UK, and USA. Some of these SDI initiatives have little to show other than good intentions, while others have already built up a considerable amount of experience in formulating and implementing national SDIs. In some countries, such as Australia and the United States, there is a growing body of published materials describing different aspects of developing and implementing SDI, including future strategic plans.

Regional Level

Based on the current progress of Regional SDI initiatives, the first two regions that have started to develop SDIs at a regional level are the Asia-Pacific and the European region. These two Regional SDI initiatives are the Asia-Pacific SDI (APSDI) and the European Geographic Information Infrastructure (EGII) which are coordinated by the Permanent Committee on GIS Infrastructure for Asia and the Pacific (PCGIAP) and the European Umbrella Organisation for Geographic Information (EUROGI) respectively. The potential benefits of developing any type of SDI, promised and documented by these organisations (PCGIAP 1998, GI2000 1995, EUROGI 1999) and different researchers (Coleman and McLaughlin 1998, Chan and Williamson 1999b, Rajabifard, *et al.* 1999) along with support from international communities, the other two regions

(Americas and Africa) are also starting to establish similar organisations to develop the same initiatives for their respective regions (Borrero 2000, Bassolet 2000).

Global Level

At the global level, there is an ongoing initiative called Global Spatial Data Infrastructure (GSDI). In this initiative, regional organisations such as EUROGI and PCGIAP are playing an important role in GSDI. GSDI is currently at an early stage of development including the development of a proper organisational model, policy and framework as well as setting different working groups for designing and conducting research on the other important components of GSDI (GSDI 1998). This initiative was defined by the participants of the Second GSDI Conference as generally encompassing "the policies, organisational remits, data, technologies, standards, delivery mechanisms, and financial and human resources necessary to ensure that those working at the global and regional scale are not impeded in meeting their objectives".

SDI HIERARCHY

Based on current SDI initiatives as summarised above, many countries are developing SDI at different levels ranging from local to state/provincial, national and regional levels. Some countries are also participating in the creation of a global spatial data infrastructure. These initiatives facilitate better management and utilisation of spatial data assets. The most important objectives of these initiatives as highlighted by Masser (1998b) are to promote economic development, to stimulate better government and to foster environmental sustainability. As a result of developing SDIs at different levels, a model of SDI hierarchy that includes SDIs developed at different political-administrative levels was developed and introduced (Chan and Williamson 1999, Rajabifard, *et al*. 2000a). Figure 2 illustrates this model in which an SDI hierarchy is made up of inter-connected SDIs at corporate, local, state or provincial, national, regional and global levels. In the model, a corporate GIS is deemed to be an SDI at the corporate level-the base level of the hierarchy (Chan and Williamson, 1999a). Each SDI at the local level or above is primarily formed by the integration of spatial datasets originally developed for use in corporations operating at that level and below.

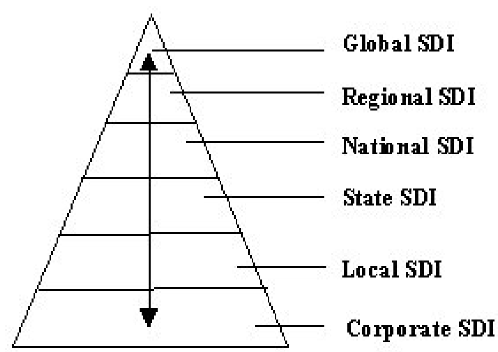

Figure 2. An SDI Hierarchy of SDIs at different levels of Jurisdictions

The main reason that a hierarchy concept is applied here, is that all common properties and reasons for developing a hierarchy structure, are also applicable on the SDIs' concepts. For example, according to the part-whole property, an element on a higher level, like a global level, consists of one or more elements on the lower level, such as different Regional SDIs. This is also applicable for applying to the individual components of an SDI. Or according to the Janus-Effect, any element at a hierarchy level, such as a National SDI in the SDI hierarchy has two different faces, one looking toward wholes in a higher level of SDI, and the other looking toward parts in lower levels of SDIs. This is also illustrated by a double-ended arrow (vertical relationships) in Figure 2. Additional to these vertical relationships there are also complex relationships between SDIs within a jurisdictional level, at a 'horizontal' level, of an SDI hierarchy.

Rajabifard *et. al* (2000a) published two views on the nature of this SDI hierarchy. The first view is an umbrella view, in which the SDI at a higher level, say the global level, encompasses all the components of SDIs at levels below. The second view is the building block view, in which any level of SDI, say the state level, serves as the building block supporting the provision of spatial data needed by SDIs at higher levels in the hierarchy, such as the national or regional levels. Based on these two views, the SDI hierarchy creates an environment, in which decision-makers working at any level can draw on data from other levels, depending on the themes, scales, currency and coverage of the data needed.

FUTURE DIRECTION OF SDI

Based on the strategies, aims, objectives, and status of individual SDI initiatives in different levels, two models namely product-based and process-based can be identified in contemporary SDI development, as illustrated in Figure 3. The product-based model, outlined in Figure 3A, represents the main aim of an SDI initiative being to link existing and upcoming databases of the respective political/administrative levels of the community. The process-based model, Figure 3B, is the second approach possible for SDI development. This model presents the main aim of an SDI initiative as defining a framework to facilitate the management of information assets. In other words, the objectives behind the design of an SDI, by any coordinating agency, are to provide better communication channels for the community for sharing and using data assets, instead of aiming toward the linkage of available databases.

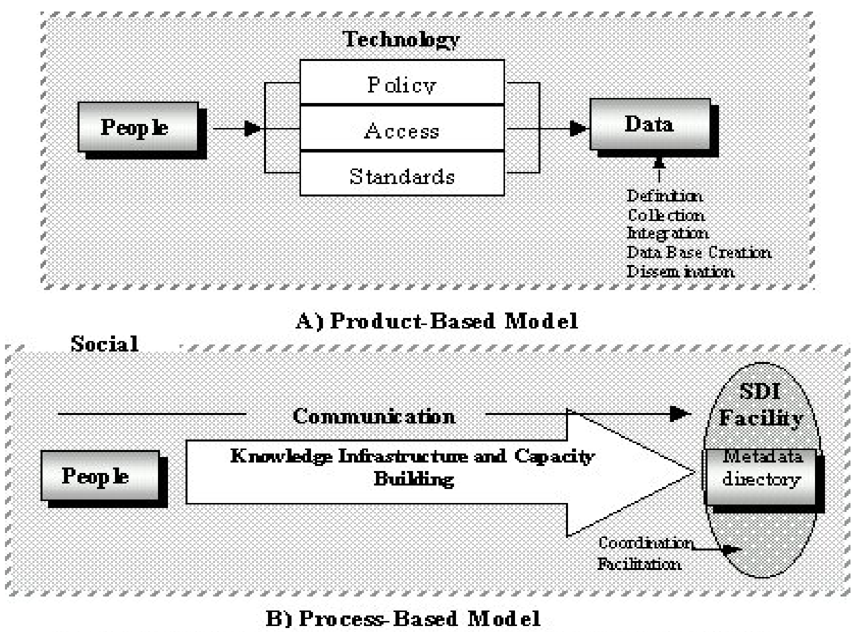

Figure 3: Product and Process based models for SDI development

The process-based model emphasises the communication channel of knowledge infrastructure and capacity building, by following certain steps towards the creation of an infrastructure in which to facilitate all parties of the spatial data community in the cooperation and exchange of their datasets. These steps are Awareness, Knowledge infrastructure, Alignment, Persuasion, Decisions, Participation and Utilisation.

In order to take full advantage of this approach, it is important to understand the social system of the community or jurisdiction in which the approach is supposed to be executed. The social system is defined by Rogers (1993), as a set of interrelated units that are engaged in joint problem solving to accomplish a common goal. The importance of this condition is that the characteristics of an innovation, like an SDI, as perceived by the members of a social system, determine its rate of adoption. The social system definition then becomes particularly influential when an innovation is developed and implemented within different communities, due to different characteristics of each community. The characteristics of the social system strongly influence the approach taken to the development of an SDI initiative. The understanding of the social system can help selection of an appropriate approach to SDI development.

SDI development using a process-based model, in its adoption among spatial data communities, obeys the S-shaped diffusion curve found by Coleman, Menzel and Katz (Coleman *et al.* 1966 cited by Rogers 1993), that characterised the behaviour of earlier and later adopters of an innovation (Figure 4). This is reflected in the degree of support in different SDI initiatives as they develop. For example, after six years of development the Asia-Pacific SDI is still only in an early stage of adoption according to the proposed Diffusion curve (Mohammed 1999). There are many issues and challenges faced by SDI development initiatives throughout the world (Onsrud 1998, Masser 1998b, Mohammed 1999) including the compatibility of the visions and expectations for a SDI and the development model selected, which justify the need to improve understanding about the alternative approaches that may be adopted whilst learning from current development experiences. In this regard, there is considerable documented experience in designing different level of SDIs. As a result there are a number of key issues and strategies to be considered within the design process:

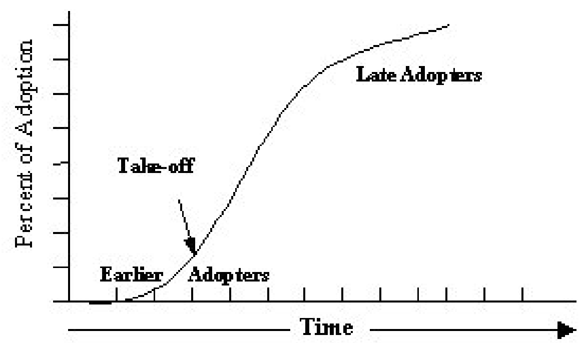

Figure 4: S-Shaped Diffusion Curve
(Adopted from Coleman *et al.* 1966)

- The development of a strategic vision and associated implementation strategy,
- The recognition that SDI is not an end in itself,
- The key institutional strategy is to have all coordinating processes administered within one government department.

CONCLUSION

This paper discussed the nature and concept of spatial data infrastructures based on current progress of SDI initiatives. Then, a spatial hierarchy relationship was outlined among the different types of SDIs. According to this model, by combining each level of SDIs using an umbrella model, it is possible to build the next level of a SDI. In other words, different levels of SDIs can build upon other supporting levels. Moreover, based on the strategies, aims, objectives, and status of individual SDI initiatives in different levels of an SDI Hierarchy, this paper introduced two models as a new vision on SDI development, namely a product-based and process-based model. Both models have value, but contribute to the evolution and uptake/utilisation of the SDI concept in different ways. They provide different frameworks for dealing with intra-jurisdictional mandates for the objectives of spatial data access and sharing.

Further, this paper introduced six key factors for the success of an SDI development. These factors include awareness of GI and SDIs, cooperation between the various users, the involvement of politicians, knowledge about availability of data, accessibility to data and use of data.

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