Geomatics Seminar, Ministry of Industries and Mines
15 May 2004,Tehran, Iran

Developing Spatial Data Infrastructures to Facilitate Industrial and Mining Decision-Makings

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INTRODUCTION

A preliminary step toward achieving decision-making for complex problems has been increasing recognition of the role of spatial information to generate knowledge, provide added value to identify problems, assist in proposing alternatives and defining a course of action, information discovery, access and use (Williamson *et al.,* 2003). The importance of spatial information to support decision-making and management of growing national, regional, and global issues, such as deforestation and pollution, was specifically cited in the 1992 Rio Declaration on Environment and Development and has been made one of the key themes in subsequent meetings of the Commission on Sustainable Development (CSD, 2001). Since the Rio Declaration' call to develop strategies to guarantee the existence of all life, not just human life, there has been acknowledgement of the need to integrate environmental and developmental aspirations at all levels of decision-making.

Decision problems that involve spatial data and information are referred to as spatial decision problems. Spatial decision problems often require that a large number of feasible alternatives be evaluated on the basis of multiple criteria, thus spatial decisions are multi-criteria in nature (Massam, 1980). Multi-criteria decision-making is more complex than that based on a single criterion, because of the difficulty finding an alternative that dominates all others with respect to all criteria. The number of people involved in the decision-making process also influences the complexity of spatial decision problems (Massam, 1988). Spatial decision problems may be characterised by different preferences with respect to the decision consequences and the relative importance of the evaluation criteria. The incorporation of values and preferences into decision-making models is an important function of multi-criteria analysis in complex decision problems, and often requires the aid of sophisticated technologies to structure the decision process and the outcomes.

Decision-makers requiring technological support for complex forms of spatial decision-making face challenges to establishing linkages between data, information and decision support systems (DSS) without spatial data infrastructure-SDI (Birk, 2000). SDIs have the potential to promote widespread use of the available spatial datasets, which are essential to optimise spatial technology support for decision-making processes, such as DSS.

However, the challenge of designing, building, implementing, and maintaining an SDI draws on many different disciplines and requires examination of a large number of factors and issues. SDI is well explained as an integrated, multi-levelled hierarchy of interconnected SDIs based on

partnerships at corporate, local, state/provincial, national, regional (multi-national) and global levels. The creation of such an infrastructure and understanding the role of dynamic partnerships within an SDI hierarchy are essential to develop any SDI initiative.

This paper discusses the nature and concept of SDIs as an infrastructure and a framework to facilitate decision-making process. The paper also discusses the SDI hierarchy, which has helped to build understanding about the importance of the relationships within different levels of SDI, to support the interactions and dynamic nature of partnerships between spatial data communities. The role that human nature plays in any endeavour based on interaction and sharing makes cultural and social factors within a business environment important to the acceptance of the SDI concept and its alignment with spatial industry and mining objectives. The paper then identifies and discusses different SDI development issues follows by addressing three major classes of factors to facilitate the development of an SDI initiative. It is argued that the development of a functioning SDI and the adoption and implementation of factors can assist decision-makers to speed up their decision-making process.

SDI – NATURE AND COMPONENTS

The need to create multi-participant, decision-supported environments to address the issues of sustainable development and improving the quality of life creates a growing need to organise data across disciplines and organisations through different forms of spatial data infrastructure (SDI). SDI is fundamentally a concept about facilitation and coordination of the exchange and sharing of spatial data between stakeholders from different jurisdictional levels in the spatial data community. In principle, SDIs allow the sharing of data, which is extremely useful for decision-making, as it enables decision-makers and other 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.

An SDI encompasses the policies, technologies, standards and human resources necessary for the effective collection, management, access, delivery and utilisation of geospatial data for a specific jurisdiction or community. The important additional component here in compare with the four basic components is people which includes the spatial data users and suppliers and any value-adding agents in between, who interact to drive the development of the SDI.

Viewing the core components of SDIs, Rajabifard *et al.* (2002a) suggested that different categories of components 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 networks, policy and standards. 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. 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.

According to this view, anyone (data users through producers) wishing to access datasets must utilise the technological components. 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.

SDI HIERARCHY

Discussion of the SDI concept also initially focussed on nations as an entity, while the last few years have seen more attention given to understanding the SDI hierarchy, which is made up of inter-connected SDIs at organisational, local, state or provincial, national, regional and global levels, as illustrated in Figure 1. Each SDI at the local level or above is primarily formed by the integration of spatial data sets originally developed for use in corporations operating at that level and below.

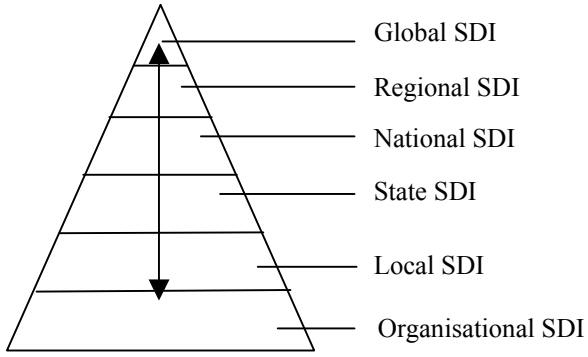

Figure 1. An SDI Hierarchy

In general the various levels in the SDI hierarchy are a function of scale with the local government and state level SDIs usually concerned with large and medium scale data, whereas National SDIs tend to be medium to small scale with regional and Global SDIs adopting the small scale for their activities. With an improved understanding of the SDI hierarchy has come the challenge to improve the relationships between SDIs in different jurisdictions as well as between different spatial data initiatives.

The key to building successful SDIs is in the establishment of these relationships, especially through mutually beneficial partnerships, which are both inter- and intra-jurisdictional within the SDI hierarchy. This is illustrates the existence of other form of relationships within the SDI hierarchy. In addition to the vertical relationships as shown in Figure 1, there are also complex relationships between SDIs within a political/administrative level, at an 'horizontal' level, of an SDI hierarchy which need to be realised as well. The vertical and the horizontal relationships within an SDI hierarchy are very complex, and this complexity is due to the dynamic, inter- and intra-jurisdictional nature of SDIs (Rajabifard *et al,* 2002b). Therefore, in order to map these relationships and take the benefits of SDI hierarchy, any SDI practitioners need to understand the role of dynamic partnerships as they are essential to develop any SDI initiatives.

SDI PARTNERSHIPS AND GLOBAL DRIVERS

It is the needs of the user community that drive SDI development. As discussed before, the design of any SDI requires understanding the nature of the concept, the contributing components and the impact of global drivers such as globalisation, sustainable development, economic reform, political unrest and war, urbanisation, environmental awareness and human rights (Williamson 2000). These present significant influences on the changing spatial data relationships within the context of SDI jurisdictions which in turn effect the resulting spatial data industry environment and SDI vision, in particular the partnership concept.

There has been a trend for countries to expand their efforts in developing SDIs through partnerships, as data sharing is crucial to the success of SDIs. In the 1990s National SDI development took a broad-base approach to encourage cooperation among stakeholders to pool data assets. Based on this approach, an ideal SDI should have all datasets in the corporate SDI fully

integrated. Constrained by existing technical and institutional arrangements, SDI developing agencies have focused on promoting adoption of common standards, as well as fast-tracking integration among certain strategic datasets through partnership arrangements (Jacoby *et al.* 2002). Partnerships are formed to create business consortia to develop specific data products or services for strategic users, by adopting a focussed approach to SDI development. It is also important to identify and understand the human and community issues as they help to better define and arrange relationships through the partnerships concept.

HUMAN AND COMMUNITY ISSUES

The significance of human and community issues is essential that SDI practitioners need to understand, as much as technical issues, as they determine and contribute to the success of SDI developments. Community issues determine the long running success of an SDI innovation. SDI, therefore, can no longer be regarded, or taught, primarily as just a technical matter. Developing a successful SDI initiative depends at least as much upon issues such as political support within the community, clarifying the business objectives which the SDI is expected to achieve, sustaining a culture of sharing, maintaining reliable financial support and enlisting the cooperation of all members of the community, as upon technical issues relating to spatial data access, networking, and standards. Therefore, developing a successful SDI within a jurisdictional level must be seen as a socio-technical, rather than a purely technical, exercise; the communities concerned are expecting to reap benefits from their investment in SDI in terms of improved corporate performances and cooperation.

For example, if the success rate of SDI initiatives is to be improved it is clear that attention needs to be paid to understanding the community and organisational issues within which SDI is supposed to be developed. The SDI initiative has evolved from information systems and technology. With this in mind, as Campbell and Masser (1995) noted that the technological imperative leads us to believe that the adoption of new technology is inevitable and the sooner we adopt the new products the greater will be our advantage. Thus, like any new technology, any community which adopts SDI sooner, will experience greater advantages.

In response to this recognition, Petch and Reeve (1999) believe a socio-technical viewpoint has increasingly been adopted with the definition of an information system being expanded to include not only the hardware and software, but also the people involved. This viewpoint is as relevant to the development of SDI initiatives and suggests the need to include people, alongside technical and institutional components, in the definition of SDI initiatives throughout the spatial data community. Figure 2, illustrates a socio-technical viewpoint in which a shift is suggested from a techno-centric position to a socio-technical position within a spatial data community.

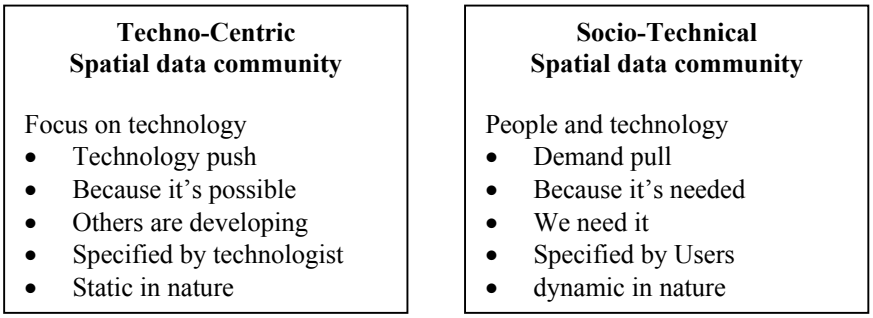

Figure 2: From a techno-centric position to a socio-technical position
(Modified from Petch and Reeve 1999)

A socio-technical conception of SDI should emerge in which it is recognised that even if it is assumed that SDI succeeds on a technical level, its adoption still will ultimately depend on how well implementation strategies address the respective community barriers. Recognising that societal issues can be critical factors in determining the success of SDIs, has meant that the SDI's coordinating agency has had to develop a much richer conception of who its community are, how they behave, and particularly how they are likely to respond to the introduction of such a new spatial infrastructure initiative.

In this respect and due to the complexity of social, cultural, political and administrative systems, and also considering individual members' own motivations and ambitions, the adoption of an SDI, no matter how impressive, is by no means assured. Whether an SDI is a success will depend upon a complex interaction of all community issues, including those relating to the sharing of information.

CULTURE FOR SHARING INFORMATION

Much of the potential for the use of knowledge lies in the ways by which knowledge may be shared. This heavily depends upon the culture of a society. All communities and societies have a culture – a system of shared meaning (Langdon and Marshall 1998). Similarly, any initiative or function, including the sharing of information, also has a specific culture which needs to be promoted to prepare the environment for developing/pursuing the specific activity. Whether that culture is weak or strong is important to both a coordinating agency and individual parties. Therefore, sharing knowledge and information requires a specific culture – a culture for sharing (Rajabifard *et al,* 2002b).

Culture is the integrated system of learned patterns of behaviour, ideas, and products characteristic of a society. It is also the ideas people have about their world. In this sense, culture is our mental map of our world and it is also a map for determining action and it becomes a guide for behaviour and decision-making. Langdon and Marshall (1998) view the organisational culture as a shared system of beliefs and values, as evident in rituals, stories, myths and often a specialised language, that fosters a feeling of belonging.

Cultural differences have also persisted between countries at similar stages in industrialisation, and it has been suggested that national culture had a pervasive influence even upon institutional, productive and managerial structures that had formerly been cited as instrumental in international organisational convergence (Neal 1998).

INFLUENCING FACTORS FOR SDI DEVELOPMENT

There are a number of important factors and issues related to SDI development from conceptual, technical, socio-technical, political, institutional and financial perspectives. Therefore, the challenge of designing, building, implementing, and maintaining an SDI draws on many different disciplines and requires examination of such factors and issues. It is essential that SDI practitioners also understand the significance of human and societal issues, all of which contribute to the success of SDI developments. It is note-worthy that these factors and issues should be considered in the long-term in order to achieve sustainable and ongoing development of SDIs.

By identifying key human and technical factors within classes of potential users, SDI coordinating agencies will be able to better define and develop their strategies to achieve their objectives. Having said that, the author has identified three major classes of factors, which are influencing, or contributing to the development of any level of SDI hierarchy. These classes of factors are

Environmental Factors, Capacity Factors, and SDI Organisation Factors, as illustrated in Figure 3. According to the following figure, the three classes of factors together effect the participation rate.

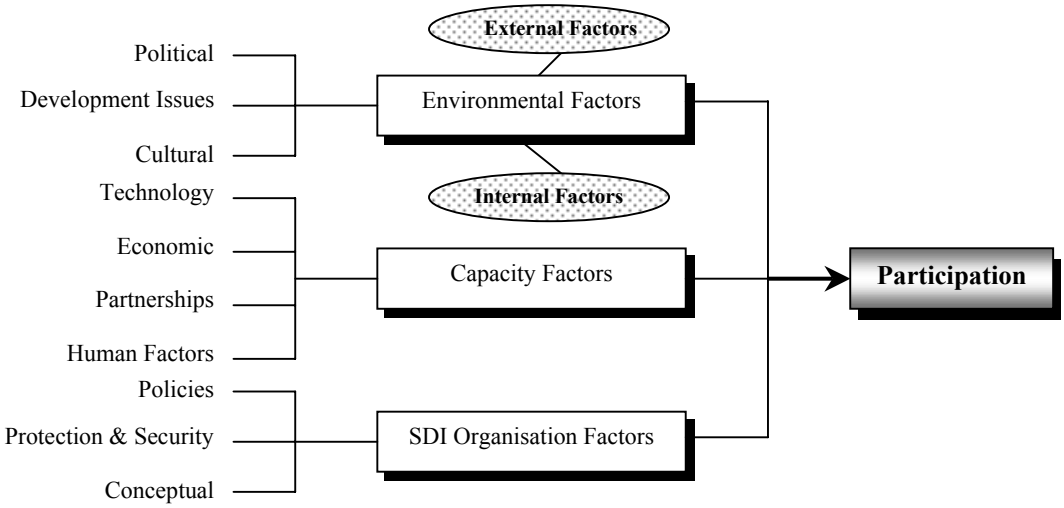

Figure 3: Factors influencing SDI development

Environmental Factors: the environment is the overall structure within which the social system operates and is characterised by internal and external factors. Therefore, the different characteristics of social systems, or communities, adopting the SDI concept can be attributed to a number of environmental factors, including the different cultures of the communities, political factors, and development issues. The external factors are those factors outside the border of the social system which affect, or could potentially affect, the performance of an organisation. These factors impinge more on management levels. The internal factors are those factors inside the border and affect both management and member levels. Therefore, determining an appropriate social border for study and analysis of a social system is very important.

In terms of effectiveness of factors, the effects of cultural factors on SDI development can be extremely high. The social dynamics of stakeholder relations can cause enormous effects on cooperation and costs within the business environment and poor decision-making. By examining the social dynamics of cultural difference within jurisdictions, it would be possible to understand why a high proportion of capabilities of members is hidden or not functioning. SDI coordinating agencies must therefore assess the impact of cultural factors in SDI development. If the risk of these factors is seen to be too high, then the strategy for development can be redesigned.

Capacity Factors: capacity building is an essential component of any institutional reform such as building land administration infrastructures or SDI. However the capacity building concept is often used within a narrow meaning such as focusing on staff development through formal education and training programmes to meet the lack of qualified personnel in a project in the short term. This conventional concept has changed over recent years towards a broader and more holistic view, covering both institutional and community specific initiatives. As defined by Georgiadou (2001), Capacity building may refer to improvements in the ability of institutions and (government and non-government) organisations to carry out their functions and achieve desired results over time. It may also refer to the provision of foundation data, metadata standards, clearinghouse functionalities and a facilitating environment for decentralising GIS application in manageable application domains within the SDI concept. Therefore, based on this definition, capacity building for an SDI in a broad

sense may refer to improvements in the ability of all involved parties to perform appropriate tasks within the broad set of principles of that particular SDI initiative.

With this in mind, Capacity Factors are those that cover technology, economic factors, partnerships, and human factors and thus encompass technological capacity, human capacity, and financial capacity.

SDI Organisation Factors: these are factors related to the way that an SDI is defined, designed and implemented. This mainly includes all SDI core components, including technical and institutional issues such as access policies, access networks, technical standards, and the SDI conceptual model. Some examples of SDI Organisation Factors are: the suitability and degree of complexity of the SDI conceptual model; the availability of spatial data and metadata; the integration and inter-flow of datasets from different parties (this has important implications for the ownership and control of information); access networks; and multiple trusted data sources.

As discussed earlier in this paper, much has been done to describe and understand the components and interactions of different aspects of SDIs and their integration into the transactions of the spatial data community. However, there is still a need for descriptions to actually represent the discrepancies between the role and deliverables of an SDI and thus contribute to a simpler, but dynamic, understanding of the complexity of the SDI concept. To this end, Rajabifard *et al.* (2002a) suggested, that the roles of SDI have been pursued through two different approaches: product-based and process-based models, which contribute to the evolution, uptake and utilisation of the SDI concept in different ways.

The product-based model, represents the main aim of an SDI initiative being to link existing and potential databases of the respective political/administrative levels of the community. Whilst, the process-based 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. In return, this can also facilitate the concept of partnerships.

CONCLUSION

The importance of spatial information to support decision-making and management of growing national, regional, and global issues has been increasing recognised. In this regard, the need to create multi-participant, decision-supported environments to address the issues of sustainable development and improving the quality of life creates a growing need to organise data across disciplines and organisations through different forms of spatial data infrastructures.

Based on this, this paper first reviewed the nature and the concept of SDIs, including the SDI hierarchy, which helped to build understanding about the importance of the relationships within different levels of SDI, to support the interactions and dynamic nature of partnerships of spatial data communities. The paper argued that SDIs are important infrastructures and frameworks for facilitating decision-making process. Then, it discussed human and community issues which are important in long running success of an SDI initiative. It further identified key factors influencing the development of SDIs. The paper presented and discussed three major classes of factors, namely Environmental Factors, Capacity Factors, and SDI Organisation Factors.

It is argued that the adoption and implementation of these factors and the selection of a proper model can assist the SDI coordinating agencies in such a way that they improve participation rate and speed up their progress in the development of the SDI initiative.

ACKNOWLEDGMENTS

The author gratefully acknowledges the support of the Centre for Spatial Data Infrastructures and Land Administration at the University of Melbourne. The views expressed in this paper are those of the author and do not necessarily reflect the views of the Centre and the University of Melbourne.

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