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Spatial Data Infrastructure Management: lessons from corporate GIS development

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ABSTRACT

It is argued that a corporate GIS is the lowest level in a hierarchy of spatial data infrastructures (SDIs) worldwide. Therefore, SDI development can benefit from a good understanding of the nature and dynamics of development of a corporate GIS. To facilitate this cross-fertilisation, existing definitions of GIS are briefly reviewed in the context of the organisational setting of a corporate GIS. A high level perspective which describes a corporate GIS as making up of GIS modules that play the roles of either an infrastructure or a business process is presented in the paper. The modules are termed *infrastructure GIS* and *business process GIS* respectively, with the former supporting the latter.

The patterns of GIS development and some long term characteristics of a corporate GIS are identified in a study of the dynamics of GIS development in the Department of Natural Resources and Environment in the State Government of Victoria. These two aspects of the nature of a corporate are also applicable to SDIs and their development. Based on the experience of SDI development in Australia, particularly Victoria, the implications of the observed nature of SDI relationships on SDI management are discussed.

KEYWORDS: infrastructure GIS, business process GIS, spatial data infrastructure, *productional* perspective, corporate GIS, Victoria, SDI hierarchy

INTRODUCTION

In support of social, economic and environmental development decisions, many countries worldwide are developing spatial data infrastructures (SDIs) at various political-administrative levels, such as, global level , regional level , national level , state/provincial level and local level . With the significant interest in SDI development, studies have

been conducted into the nature and characteristics of different national/regional SDIs and strategies adopted in developing national SDIs .

This paper aims to contribute to the discussion of SDI development in Australia. It first points out that current SDI initiatives worldwide can be grouped into a hierarchy of SDIs with corporate GIS forming the lowest level in the hierarchy. The paper then examines the nature of a corporate GIS identified in a study of the dynamics of the long term GIS development in the Department of Natural Resources and Environment (DNRE) and its precursor departments in the State of Victoria in 1997. The experience of SDI development in Australia demonstrates that the nature of corporate GIS observed from DNRE is also applicable to a significant extent to SDIs. The paper concludes by discussing the implications of the characteristics of SDIs identified on SDI development.

SDIs AND CORPORATE GISs

Based on a working definition proposed by Coleman and McLaughlin , the Second Global Spatial Data Infrastructure Conference defined a global SDI as encompassing 'the policies, organizational 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' . The definition is also applicable to SDIs at other political-administrative levels by extending its 'scale' to include other levels. The Conference also resolved to 'encourage the creation, development and linkage of local, national, regional and global geospatial data infrastructures', and to 'explore the extent to which local, national and regional data sets can be translated into international ones' . The conference recognised that the Global spatial Data Infrastructure would have to draw on datasets developed by local, national and regional SDIs.

The same approach of data sharing and integration is also adopted in building the regional SDI in Asia-Pacific , the national SDIs of Australia and the U.S.A. , and the state SDI of Victoria, Australia . Based on the belief that all spatial datasets are best maintained at their source, the SDIs at different political-administrative levels should ideally be drawing their data, either directly or indirectly, from existing spatial datasets originally developed by organisations to meet their specific business needs. For example, Australia's state and national SDIs develop their cadastral components from the digital cadastral (land parcel-based) databases maintained by the state mapping agencies for mapping and other land administration purposes.

An ideal integrated corporate GIS would have datasets that are shared by all users in the organisation . In the context of the global SDI as defined above, the spatial datasets in association with policies, organisational remits, technologies, standards, delivery mechanisms, and financial and human resources inherent in the integrated corporate GIS of an organisation constitute a SDI, a corporate SDI. As other levels of SDIs will all draw on the spatial datasets from the corporate SDIs, the corporate SDIs form the base level in the hierarchy of SDIs as illustrated in Figure 1. As a corporate GIS/SDI is formed primarily by sharing and integrating data from different business units in an organisation, development of SDIs at other levels can benefit from an understanding of the dynamics of development of a corporate GIS.

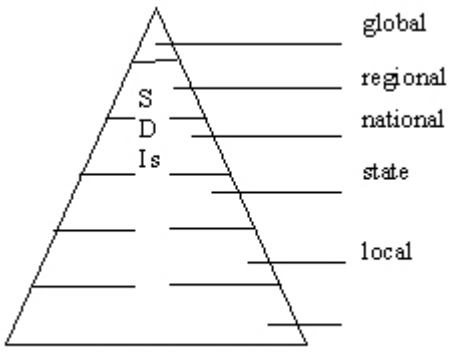

Figure 1. Hierarchy of SDIs

THE NATURE AND DYNAMICS OF DEVELOPMENT OF A CORPORATE GIS

Before examining the dynamics of development of a corporate GIS, it is necessary to know the nature of a corporate GIS. Chan and Williamson reviewed three existing perspectives of GIS: the *identificational* perspective highlights the unique characteristics of GIS; the *technological* perspective focuses on the forms and functions; the *organisational* perspective emphasises the generic elements of GIS, particularly the organisational environment. Based on the theories of innovation diffusion , Chan and Williamson argued that existing perspectives of GIS were inadequate in describing a corporate GIS which was dynamic and unpredictable in the long term.

They developed a *productional* perspective from the Organisational Theory, which portrays a corporate GIS as an integral part of the production process of an organisation (Figure 2). In such a corporate GIS, certain collections of GIS capabilities (GIS modules) have the function of directly generating the products and/or services required of the organisation. These modules are called *business process GIS*. The remaining GIS modules support the development and functioning of the *business process GIS* and are called *infrastructure GIS* . Both groups of GIS modules include the five generic elements of GIS, that is, *data*, *standards*, *people*, *information technology* and *organisational setting* .

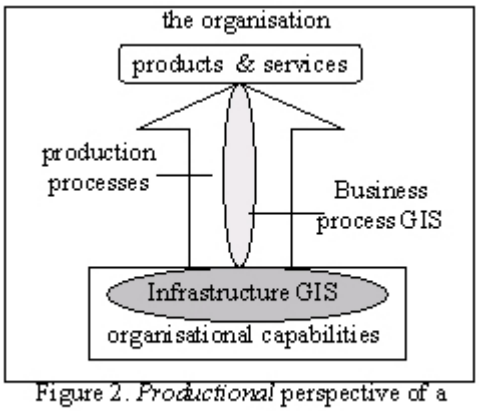

Figure 2. *Productional* perspective of a corporate GIS

Using the *productional* perspective of GIS, Chan and Williamson examined the dynamics of GIS development in DNRE and its precursor departments over an 18-year period from 1979-1997. In the process they identified four patterns of GIS development and some long term characteristics of a corporate GIS . The next two sub-sections briefly report their findings in these two respects.

Patterns of GIS development

The case of GIS development in DNRE and its precursor departments reveals that concerted effort from junior and middle managers is a prerequisite for initiating and sustaining GIS development. There are four patterns in which a corporate GIS can be built up from its component GIS modules, that is, the *infrastructure* and *business process GIS*. The patterns are called *opportunistic*, *systematic*, *opportunistic-infrastructure* and *opportunistic-business process*.

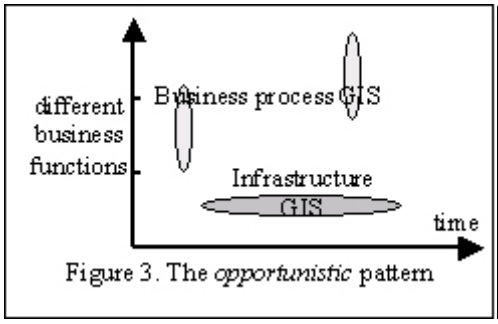

Figure 3. The *opportunistic* pattern

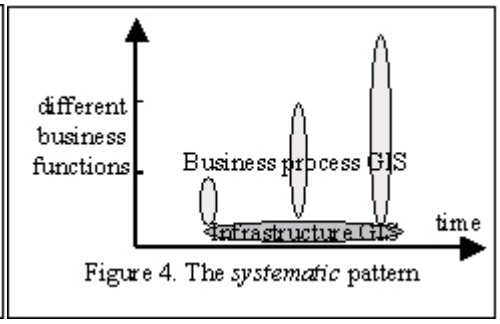

Figure 4. The *systematic* pattern

The *opportunistic* pattern indicates development of GIS modules that is ad hoc and uncoordinated. There is no support from senior management, and the managers developing the GIS have a restricted GIS vision that focuses on the needs of their respective business functions. Figure 3 illustrates such a pattern in which three independent GIS modules are developed in three different business functions over time. The outcome is an unintegrated corporate GIS.

In the *systematic* pattern, the development of the GIS modules of the corporate GIS is structured and well planned. There is concerted support from managers at all administrative levels, who have a broad vision to develop a GIS that serves the whole organisation. Figure 4 illustrates such a pattern in which three modules of *business process GIS* are sequentially developed together with a module of *infrastructure GIS* over time according to an implementation plan for three business functions. The outcome is a fully integrated corporate GIS.

In the *opportunistic-infrastructure* pattern, a module of *infrastructure GIS* is developed first to support the development of other modules of *business process GIS*. The managers driving the development of the GIS have a vision to develop the technology to serve the entire organisation and are able to gain the support of senior management to start the GIS development process. Figure 5 illustrates such a pattern in which the managers are able to start developing an *infrastructure GIS* with senior management support. However, the support is not sustainable. GIS managers have to undertake three GIS projects (business process GIS) on behalf of three different business

functions to mobilise resources from other parts of the organisation to sustain the development of the *infrastructure GIS*. Depending on the strategies of the managers, and other subsequent inputs from senior management, the resulting corporate GIS may or may not be integrated.

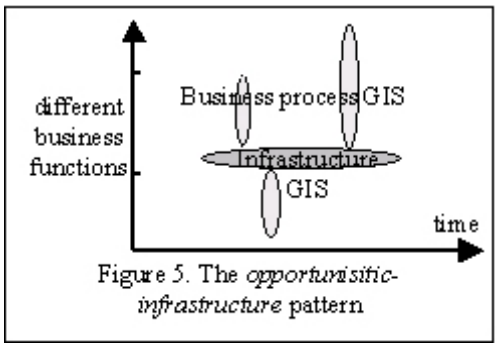

Figure 5. The *opportunisitic-infrastructure* pattern

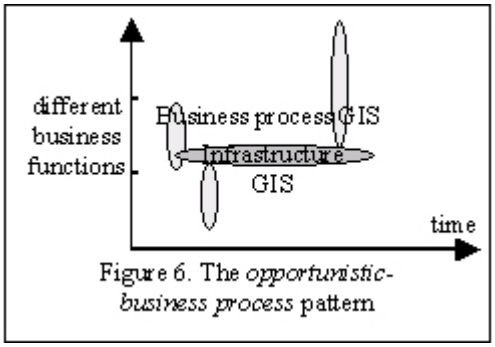

Figure 6. The *opportunistic-business process* pattern

The *opportunistic-business process* pattern is similar to the *opportunistic-infrastructure* pattern except that senior support is uncertain and is not secured early on. As illustrated in Figure 6, managers driving the development process have to use whatever resources available in a business function to develop a module of *business process GIS* first. This module is subsequently used to help other business functions to develop their GIS capabilities (*business process GIS*). As a result, the original module of *business process GIS* acquires an additional role of an *infrastructure GIS*.

In the very dynamic organisational setting of DNRE and its precursor departments, senior management support is highly uncertain. As a result, this pattern has been very popular among many resourceful managers in DNRE in the realisation of their GIS visions in the past. Depending on the detailed strategies adopted and the extent of senior management involvement, the resulting corporate GIS may or may be integrated.

Long term characteristics of a corporate GIS

The case of GIS development in DNRE and its precursor department has helped to validate the *productional* perspective of GIS: a corporate GIS is a dynamic and modular entity that is made up of two basic modules termed *infrastructure* and *business process GIS*. Based on this perspective and the four patterns of GIS development, Chan and Williamson also identify four main long term characteristics of a corporate GIS. Firstly, *Infrastructure GIS* and *business process GIS* need one another to develop effectively and efficiently. *Infrastructure GIS* does not and should not develop in isolation of the *business process GIS* it supports.

Secondly, the varied and changing information needs of the business units make it almost impossible to clearly define the long term composition or capabilities of a corporate GIS beforehand. Over time, the modules of *infrastructure GIS* gradually evolve into an inter-related, functionally multi-levelled entity, with each module of *infrastructure GIS* at each level providing specialised GIS products and services to the business units.

Thirdly, the GIS services and products provided by one *infrastructure GIS* to other GIS modules form links among the GIS capabilities in different business functions of an organisation. The links can be tight or loose. Tight links in the form of common data model, format and sources, compatible/interoperable hardware and software, produce a better-integrated corporate GIS. The best integration is achieved in a *systematic* pattern of GIS development in which all GIS capabilities are centrally determined. Integration is significantly weaker when one *infrastructure GIS* provides other GIS modules with products or services that do not conform to a common set of standards.

Fourthly, though the *systematic* pattern can ensure the development of an integrated corporate GIS in the short term, none of the four patterns of GIS development can guarantee development of such a corporate GIS in the long term.

RELEVANCE TO SDI

According to the *productional* perspective, the shared spatial data and the associated elements of a GIS are the modules of *infrastructure GIS* of a corporate GIS. The section on ‘SDIs and Corporate GISs’ has argued that the shared spatial datasets in an organisation ‘in association with policies, organisational remits, technologies, standards,

delivery mechanisms, and financial and human resources inherent in the integrated corporate GIS of an organisation constitute a SDI, a corporate SDI'. Therefore it is expected that the patterns of SDI development observed should be similar to those of GIS development. SDIs should also exhibit similar characteristics as the *infrastructure GIS* in a corporate GIS. The rest of this section illustrates these relationships by drawing on the experience of SDI development in Australia, particularly Victoria.

The *opportunistic* pattern

The development of the jurisdictional SDIs (including state, territories, and the Commonwealth) in Australia over the past ten to fifteen years is an example of the *opportunistic* pattern. Despite the coordination by the Australia New Zealand Land Information Council to develop a national SDI, there has been limited support from senior politicians in the jurisdictions for such a vision. By and large, each jurisdictional SDI developed independent of one another. The resulting national SDI of Australia is unintegrated, and the spatial datasets are not compatible with one another.

The *systematic* pattern

A good example for the *systematic* pattern of SDI development is difficult to find as such a pattern requires concerted support from all levels of managers, including politicians. The composition and functionality of the SDI have to be well defined and built according to an implementation plan. One initiative that comes close to the *systematic* pattern is the LANDATA project which was initiated in Victoria in 1984 after a decade of gestation and planning. Under a detailed corporate plan LANDATA was established to coordinate the development of three broad components of the Victorian SDI: a legal/fiscal (land information) system, a digital mapping system (cadastral) and a natural resources system . The three components started as independent projects under LANDATA but there was a plan to integrate the cadastral map base with the land information system in due course.

The land information system was to be a common system to support land administration activities such as survey and mapping, land tax, title registration, land valuation, public utility management and local government administration. However, the agencies responsible for the respective land administration activities all had their own agenda. They were not cooperating fully as many of them were worried that a common land information system might result in significant job losses in their respective surveying and mapping offices. (Holmes 1997)

The Surveyor General was responsible for producing the digital cadastral and topographic map bases. These two projects progressed smoothly. However, the two digital map bases were primarily produced for mapping purposes and were therefore produced in the cheaper, computer-aided-drafting (CAD) format. The limited resources available to the project prevented the Surveyor General from producing digital topographic data in the more expensive GIS-based format to meet the requirements of the natural resources sector. (Holmes 1997)

Despite comprehensive planning and support from all levels of government initially, the project was ahead of its time. There were many stakeholders who had their own agenda. The development of the land information system was slow as the full cooperation of the many agencies involved was lacking. The prevailing cost recovery policy at the time simply hastened the loss of government support. Aggravated by the dissatisfaction of the natural resource sector, the project was stopped in the late 1980s, leaving behind a Victorian SDI that comprised a public inquiry service for land titles information and the digital cadastral and topographic map bases. These components were not integrated.

The *opportunistic-infrastructure* pattern

A good example of the *opportunistic-infrastructure* pattern is the development of the Victorian SDI by the Office of Geographic Data Co-ordination (OGDC) in the early to mid-1990s . This initiative started with a comprehensive government wide GIS planning study to identify the business processes that could benefit from GIS. The necessary SDI, the State Geographic Data Architecture, to support these business processes was identified with a set of implementation strategies.

The GIS planning study took an economic rationalist approach and predicted an over five-fold return of investment from the SDI in a six-year period. This gained the initial support of the senior management and the Cabinet. However, senior management and the Cabinet had a broader economic rationalist agenda. They did not provide

sufficient resources to implement the strategy in full. They did not nurture the development of OGDC and expected it to remain small (an office of five) and to be self-sufficient in due course. In addition to being the GIS coordinator and authority, they also asked OGDC to take over and privatise the mapping function of the State. This provided OGDC with the first opportunity to bring both the DCDB and the digital topographic databases together to develop an integrated SDI.

The new authority came with new responsibilities. Senior management and the Cabinet required OGDC to use the SDI to develop the state digital road network needed for the State's new computerised emergency dispatch system. They also required OGDC to manage the digital spatial datasets under its charge in a commercial manner and to recover the production cost through a users-pay policy. OGDC was in effect turned into a show case for economic rationalism and given an unexpected business function of supplying, marketing and distributing the state's core spatial datasets. This additional business function prevented OGDC to fulfil its original role as a GIS authority and coordinator.

After struggling unsuccessfully to meet the expectations of all the stakeholders, OGDC was restructured under the policy of economic rationalism of the government and put under DNRE in 1996. The overall GIS/SDI strategy for Victoria was revised in 1997. The effort by OGDC to develop Victoria's SDI failed to achieve all the objectives as originally planned. However, OGDC was able to bring the key spatial datasets together to form the integrated State Digital Map Base.

The *opportunistic- business process* pattern

As pointed out earlier in the paper, the *opportunistic-business process* pattern is the most popular pattern of GIS development in the absence of sustainable senior management support. The experience of SDI development in Victoria suggests that the *systematic* and *opportunistic-infrastructure* patterns are not conducive to successful SDI development. The *opportunistic-business process* pattern is the approach used to sustain the continual development of Victoria's SDI, particularly its cadastral component.

The first digital map in Victoria was prepared in 1983 by the State mapping office. It was a 1:250 000 topographic series map. Since then, the development of the digital spatial databases in Victoria was tightly coupled to the mapping function of the State for which the cheaper CAD format was sufficient. There was no need for the more expensive GIS-based format. In 1986/7, preparation of the digital cadastral database (DCDB) of rural Victoria was started using resources provided under the LANDATA project. As the DCDB was produced to support the production of cadastral maps, again it was prepared in CAD format.

At the same time, the water authorities for the two major urban areas in Victoria, that is, the Melbourne metropolitan area and the Geelong area, had been busy digitising their DCDBs for their respective areas to help with asset and customer management. Unlike the rural DCDB, which was developed primarily for mapping purposes, these two urban DCDBs were developed independently to satisfy the needs of the water industry. The three DCDBs were originally developed as part of two business functions: mapping and water utility management.

The role of the DCDBs as an infrastructure that support many other business applications was identified in the 1993 GIS planning study. By 1995, OGDC was able to bring the state's DCDBs and the digital topographic databases together to form the State Digital Map Base. OGDC then took on an additional business function to produce, market and distribute digital data to users in different business functions both in the public and private sectors in the State, including the municipalities. In response to the expressed requirement for GIS-based data, OGDC added topological structure to the Map Base, maintained and distributed the consolidated DCDB with the help of a private contractor. Again the DCDB was upgraded in association with a business function—supply of spatial data.

As the users got more experienced with the DCDB, they requested for more features, such as street addresses and property information. As it is the municipalities that own these data, Land Victoria, the successor of OGDC, embarked on the Property Information Project in 1997 . Funded by the State Government, the project aimed at forming partnerships with all the municipalities in Victoria. The partnerships would allow the State Government to upgrade the state DCDB with the often more up-to-date municipal DCDBs, street address and property data. This time the state DCDB is upgraded in association with the local government administration function.

At a national level, the *opportunistic-business process* pattern also accounts for the production of the 'first-cut' of

the national DCDB of Australia. In 1992 the jurisdictional mapping agencies in Australia formed a commercial consortium called the Public Sector Mapping Agencies to bring the jurisdictional DCDBs and digital topographic databases together to provide the Australian Bureau of Statistics with a single national mapping base for the 1996 census . The mapping base subsequently provided a spatial framework for other demographic and social-economic analyses involving the census data. Many organisations in both the public and private sectors have also expressed interest in using the database in their business functions . As a result the 1996 Census helped to fund the production of the first cadastral component of the Austalian SDI.

In the past fifteen years, the Australian jurisdictional governments, particularly the Government of Victoria, have consistently made use of the data originally generated for different business functions to create and upgrade the cadastral component of the national and jurisdictional SDIs—the national and Victorian DCDBs. This is a good example of the *opportunistic-business process* pattern of SDI development.

Nature of a SDI

The experience of SDI development in Australia at both the jurisdictional and national levels as cited in the previous sub-sections indicate that the patterns of development of a corporate GIS are also applicable to SDI development. One characteristics of a SDI that can be derived from these patterns of SDI development is that, like a module of *infrastructure GIS,* a SDI does not develop in isolation. This characteristic is illustrated by observations described below.

In the example of the development of the Victorian SDI cited for the *systematic* pattern, the development process was closely associated with the business functions of mapping and land administration. In the *opportunistic-infrastructure* pattern, while the SDI was intended to cater for all the business functions of the State Government of Victoria, the SDI development exercise became closely associated with the unexpected business function of supplying, marketing and distributing data, which was imposed by the government. In the *opportunistic-business process* pattern, the cadastral component of the Victorian SDI was built from datasets developed originally for business functions such as mapping, water utility management, and land administration in local governments. The development of the cadastral component relied on the resourcefulness of the managers to capitalise on the opportunities arisen, and was not planned beforehand. Even in the *opportunistic* pattern which suggests that the individual jurisdictional SDIs were developed independent of one another, the experience of Victoria described above suggest that each component of the jurisdictional SDI would have developed in association with one or more business processes in the respective jurisdiction. These observations from the four patterns of SDI development suggest that each component of the SDI always develops in association with at least a business function. This matches the first long term characteristics of a corporate GIS described earlier in the paper.

The close association of the development of a component of a SDI with at least one business function also suggests that the SDI component will be developed to suit that business function. This was true in the LANDATA project of Victoria, in which the digital topographic map base was developed primarily for mapping. As a result, the map base acquired a CAD-based format not suitable for natural resource management functions. Nationally, the map base produced by the Public Sector Mapping Agencies for the 1996 Census was a static DCDB product that was not kept up-to-date. While such a map base is suitable for the Census, it is not useful to the utility companies that require current land sub-division information.

Even when a SDI is developed with a particular business function, that business function may eventually find that the SDI is unable to meet its full data requirement. For example, the water utility companies in Victoria originally developed the urban DCDBs as a parcel-based product. However, they subsequently found that they also need property and street address data in addition to the parcel data. This is one of the reasons why Land Victoria embarked on the Property Information Project. This also illustrates the dynamic nature of SDIs.

Therefore when an organisation acquires a component of, say, a state SDI for its internal use, it may have to upgrade the component by introducing specialised capabilities to suit the needs of its various business functions. As a result the component of the state SDI goes through a value-adding process and transforms into a corporate SDI. In certain cases, the specialised capabilities may be so useful that other organisations in the state may want access to them. As a result the specialised capabilities acquire an additional role as part of the state SDI. In effect, the state SDI appears to have extended into a functionally multi-levelled entity that matches the second long term characteristic of a corporate GIS.

In the case of an integrated corporate GIS, the specialised capabilities developed by a module of *infrastructure GIS* are available to other users. This is not so for a state SDI. It may not be feasible for other organisations to make bilateral arrangements to access these capabilities for various technical, organisational or commercial reasons, or simply because of the amount of work involved. This creates a demand for the state SDI to incorporate the capabilities and make them easily available to the rest of the community.

This is not an easy task for a state SDI to incorporate the special capabilities. In Australia the state licenses users to use different components of its SDI in return for a fee. As a result, there is no incentive for the organisation that has added value to the original components of the state SDI to hand over the specialised capabilities back to the state SDI. This one-way relationship between state SDI and corporate SDI discourages the development of links that connect the different functional levels of the state SDI together into an integrated whole. This is in contrary to the third long term characteristic observed for a corporate GIS.

In order to incorporate the special capabilities as part of the state SDI to make them more accessible to the wider user community; a new form of arrangement is needed, often in the form of partnerships. One example of such a partnership is created between the State Government of Victoria and the local councils in the state through the Property Information Project. The Project aims at incorporating the improvements, including the property and street address data, made by local councils back to the state DCDB. Under the circumstances, integration within the state SDI is achieved not so much by a common set of standards but by partnerships. Based on the experience of SDI development in Australia, even the *systematic* pattern will not guarantee the development of an integrated SDI. This is in line with the fourth long term characteristic for a corporate GIS.

IMPLICATIONS FOR SDI MANAGEMENT

The nature of SDI discussed in the previous section has significant implications on SDI management. The implications as set out below will hopefully provoke healthy debate in the GIS community regarding Australia's approach to SDI development.

Firstly, a SDI is a very dynamic entity and it is very difficult, if not impossible, to fully define its long term composition and capabilities beforehand. Ideally a SDI should support a wide range of business functions. Past experience in Australia, particularly that in Victoria, suggests that developing an ideal SDI to serve a wide range of users and business functions takes a long time. It is also difficult to justify and to sustain in the current environment of economic rationalism. In practice, each component of the SDI (cadastral, topographic, land use or others) is likely to develop in close association with at least one business function.

Therefore, SDI developing agencies should be sensitive to the needs of SDI users. Instead of asking all the users to wait while the ideal SDI is being developed, a 'first-cut' of the SDI can be developed quickly to meet short term targets and the immediate needs of priority users. At the same time users can work and experiment with the components of the 'first-cut' SDI and decide realistically what they want out of it. The SDI developing agency can then upgrade the less than perfect SDI repeatedly to meet the evolving but better defined needs of the spatial information industry and the wider community.

Secondly, even when a SDI component is developed in association with a specific business function or user organisation, it will probably not meet the changing requirements of these users. The user organisation or a third party service provider may have to develop special capabilities to upgrade the component to make it useful to the other business functions in the organisation. When such special capabilities are also needed by the wider community of users, the SDI developing agency will be expected to upgrade the SDI component accordingly. Driven by its business requirements, the organisation or service provider will do a better job to improve the SDI component than the SDI developing agency. Therefore instead of acquiring the expertise and resources to upgrade the SDI, it may be more cost-effective and cost-efficient to incorporate the special capabilities into the SDI component.

Thirdly, under the influence of economic rationalism, few organisations are willing to share its special capabilities with other organisations. Therefore, SDI developing agencies encourage the formation of partnerships with the users to upgrade the SDI. In this way integration is achieved through partnership. While agreed standards can facilitate the partnership, it is the business needs of user organisations and the resourcefulness of SDI developing managers that are driving the formation of partnerships.

The Australian New Zealand Land Information Council (ANZLIC) has recently recognised the importance of partnerships in the development of the Australian SDI through the introduction of the Australian Spatial Data Infrastructure Partnership Program in early 1999 . This is notwithstanding that the definition of the Australian SDI adopted by ANZLIC has been perceived to be data-centric and to represent the spatial data suppliers' view of SDI . This is in contrary to the nature of SDIs and the dynamics of their development, which stress close interaction between the SDI developing agencies and their users (business functions), as highlighted above. It is perhaps timely to examine the definition for the Australian SDI and see if it can be refined to foster cooperation between the data users and suppliers in the development of SDIs.

CONCLUSIONS

This paper points out that corporate GISs form the lowest level in a SDI hierarchy. Managers responsible for SDI development at higher levels in the hierarchy can benefit from the experience of developing a corporate GIS. A brief review of the identities of GIS suggests that the *productional* perspective of GIS is more suitable to study the diffusion of GIS in an organisation. This perspective disaggregates a corporate GIS into two basic modules: *infrastructure GIS* and *business process GIS*.

The perspective was applied to a study of the dynamics of GIS development in the Department of Natural Resources and Environment and its precursor departments in Victoria over an 18-year period. Based on the sequence of development of the two basic modules of GIS, four patterns of GIS development are observed, namely, *opportunistic*, *systematic*, *opportunistic-infrastructure*, and *opportunistic-business process*. From these patterns four long term characteristics of a corporate GIS are also identified. Briefly, the first characteristic is that modules of *infrastructure GIS* develop in association with modules of *business process GIS*. The second is that modules of *infrastructure GIS* in a corporate GIS tend to specialised into multi-levelled entities functionally to serve the needs of the business functions in the organisation. The third is that the corporate GIS is integrated by links, or specialised services, developed among modules of *infrastructure GIS*. The fourth is that no pattern of GIS development can guarantee the formation of an integrated corporate GIS in the long term.

The experience of Australia, particularly Victoria, suggests that SDI development also follows the same pattern of development as a corporate GIS. SDIs also have similar long term characteristics of a corporate GIS but there is one major difference. The SDI capabilities develop at one level are not easily taken up by users at another level under existing working arrangement. Special partnerships are required to make that happen and to integrate SDI capabilities at different levels as a result.

The paper concludes by highlighting the implications of these insights into the nature of a SDI and its development on SDI management. A SDI should be managed as an evolving entity with its capabilities created and upgraded in the shortest possible time to cater for the needs of priority users, and to justify and sustain its development. The SDI can be upgraded in a cost-effective way by incorporating the new SDI capabilities developed by users. However, this is not possible unless special partnership arrangements are put in place. Managers of SDI developing agencies should therefore add partnership development to the list of management skills needed to meet their objectives. The close relationship between suppliers and users of SDI in SDI development also throws doubt on the relevance of the current supplier-oriented definition of the Australian SDI in reflecting the needs of the Australian spatial information industry.

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