The Governance of Spatial Data Infrastructure: A Registry Based Model

Paul Box

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Centre for Spatial Data Infrastructures and Land Administration
Department of Infrastructure Engineering
The University of Melbourne
Victoria, Australia

Abstract

This research is motivated by the desire to contribute to addressing what is increasingly recognised as a significant challenge to Spatial Data Infrastructure (SDI) implementation, namely its governance. Governance provides an enabling decision-making and accountability framework within which a community cooperates to achieve collective goals. SDIs which address the goal of sharing, accessing and using geospatial resources are rapidly developing around such communities, based upon interoperability standards and service-oriented architectural patterns. These communities vary greatly in thematic and geographic scope, level of mandate and resources, and technical capacity. With increased social and technical complexities and inter-relatedness of SDI initiatives, the design of effective governance becomes a significant challenge.

Despite the recognized importance of SDI governance there is a lack of consensus about key concepts. Furthermore, there has been relatively limited research into SDI governance challenges and potential approaches to addressing them. Without a sound theoretical basis for understanding governance and its priority challenges, it is not possible to develop appropriate, scalable, broadly applicable SDI governance solutions.

This thesis describes research undertaken to explore current understandings of SDI governance and its challenges and to develop a model for SDI governance to guide operational responses and inform further research. The research comprised literature review, case study analysis and the development of an SDI governance model.

A review was undertaken of governance literature across a range of relevant contexts to explore core concepts and identify principles, patterns or mechanisms that potentially might be applied to SDI governance. This review provided an important foundational conceptual framework for SDI governance. Emerging trends in public governance, such as the recognition of emergent heterarchical governance models, provided important insights, and a deeper understanding of public governance proved useful in framing an understanding of SDI governance which is embedded within, and must effectively interact with, broader governance contexts within which it operates.

A review of SDI governance literature made apparent that little attention has been given to exploring or defining the requirements for an SDI governance model. For the purposes of this thesis the SDI governance challenge was articulated from a resource governance perspective. SDI typically comprises complex interacting individually and collectively defined, owned and operated resources. Effective SDI implementation entails ensuring that these resources deliver a coherent set of functions to users. Coherence of resources requires agreement about many different aspects of the resources from policy to operational levels. Thus SDI governance effort needs to focus on addressing geospatial resource cohesion.

Given the contested, complex, evolving, subjective, and multi-faceted nature of SDI and its governance, there is tremendous variability in how SDIs are conceptualized in theory and realised in practice. Therefore an exploratory case study approach was used to explore the realities of SDI governance in practice using four Australian case studies.

The SDI governance model presented in this thesis is based on governance concepts drawn from other fields, a review of SDI governance literature and analysis of Australian case studies. The model is articulated around the 'three + one' dimensions of governance, that is: 'the who'- stakeholders, 'the what' – scope of governance; 'the how' – mechanisms, and 'the when' – handling change. The model defines the scope of SDI governance in terms of an institutional framework and two distinct decision domains covering social and technical concerns, with the model being focused on the governance of the technical decision domain. This separation of concerns is based on the insight that research into and implementation of SDI governance has to-date focused largely on the institutional arrangements and addressing the needs of the socio-governance domain, i.e. dealing with policy, strategic decisions and the governance environment itself. By contrast, the technical domain is concerned governing agreements about how geospatial resources behave and the realisation of those agreements in terms of geospatial resources such as software components or information resources that actually comprise the SDI.

The model represents an integrated socio-technical governance solution, comprising processes, roles and a technical framework to support submission, management and use

of agreements (the products from authority structures) and the geospatial resources that implement the agreements. These are based on the ISO 19135 Standard for Registration of Geographic Items which specifies the use of registries, with registration processes and associated roles that enable a community to govern shared information resources.

This approach focuses on achieving the interoperability of geospatial resources. This resource-centric approach enables lightweight and scalable governance with effort commensurate with scale of the SDI. Governance of SDI resources is achieved through clearly defined registration processes that capture and maintain detailed metadata about resources. The ability to discover geospatial resources together with the agreements that provide rich metadata about the syntax and semantics of resources will assist in promoting reuse and thus achieving interoperability across SDI initiatives. The ability to federate registers governed within different communities, offers significantly improved prospects for achieving interoperability within and between SDI both horizontally across domains as well as hierarchical aggregation of information resources.

This model addresses the complexity of overlapping involvement of stakeholders in multiple roles related to multiple registers in multiple initiatives that exist in practice e.g. an agency in one jurisdiction as member of control body for a thematic SDI in another jurisdiction. The elaboration of governance through the creation and operation of registers represents a formal, top-down hierarchical approach to governance. Assignment of roles for governing and submitting content of registers supports a bottom-up networked community engagement model. Thus the registry based approach enables, rather than precludes, the interaction of complex interwoven network and hierarchical governance mechanisms i.e. it supports heterarchical governance.

The model is considered to be a valuable contribution not only to improving the quality of governance but to addressing fundamental underlying challenges that SDI implementation is designed to address i.e. delivering seamless interoperable information resources for end user (re)use across SDI.

Declaration

This is to certify that

- *the thesis comprises only my original work towards the masters;*
- *due acknowledgement has been made in the text to all other material used; and*
- *the thesis is 30,000 words in length, exclusive of tables, maps, bibliographies and appendices*

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1. Introduction

1.1 Background

Although efforts to develop Spatial Data Infrastructures (SDIs) ranging from sub-national to global scale have been underway for almost two decades, the promised benefits have not yet been fully realized (Budhathoki and Nedovic-Budic 2006) . Efforts to date have focused primarily on addressing technical challenges related to sharing information. Furthermore, most of focus has been on single SDI, with limited efforts addressing interoperability between SDIs. The Infrastructure for Spatial Information for Europe (INSPIRE) is a rare example of one such inter-SDI initiative (European Parliament 2007).

It is an accepted notion that SDI success depends on resolving social as well as technical barriers associated with implementation (Rajabifard, Feeney et al. 2002, Kok and van Loenen 2005, Masser 2005, Masser 2005, Dessers, Hendriks et al. 2009) (Rajabifard, Feeney et al. 2002). Furthermore, SDI is increasingly viewed as information infrastructure (II) (Georgiadou, Puri et al. 2005, Budhathoki and Nedovic-Budic 2006, Aanestad, Monteiro et al. 2007) and from this perspective, SDI implementation is an interwoven socio-technical endeavor, recognizing that such things as work routines and organisational roles are interwoven with the information and technology resources used within the infrastructure. Growing an II thus involves "enrolling actors through aligning their interests and practices" (Kok and van Loenen 2005 p. 15). Institutional arrangements have long been recognized as a key enabler for SDI (Coleman and McLaughlin 1998) enabling community efforts to build and maintain geospatial infrastructure. However, the social dimension of II covers a much broader scope of concerns than institutional arrangements, including approaches to coordination, motivation for collective action and participation, trust and governance. Given the large number and complexity of relationships between stakeholders in the context of SDI implementation, addressing these issues is challenging.

Governance is a central concern of SDI as it provides an accountability framework that enables collaboration and the building of trust necessary for reuse of component systems. Governance comprises: the rules, policies and mandates; institutional

frameworks and arrangements; processes; and tools that enable a community to develop, manage and communicate agreements and their implementations in the form of information systems which facilitate access to geospatial data resources.

Poorly designed or articulated SDI governance can be a significant impediment to SDI implementation. However, there has been little research which explores the breadth of technical and social governance arrangements possible for SDI and thus there is a lack of consensus about key concepts. Without a sound and agreed upon theoretical basis for understanding governance, it is not possible to develop appropriate, scalable, broadly applicable SDI governance solutions.

1.2 Problem statement

A lack of shared understanding of the scope, functions and challenges of SDI governance and its relationship to other aspects of institutional arrangements and individual and collective activities that are critical SDI enablers, leads to ad-hoc, reactive governance which in turn hinders effective implementation, growth and evolution of SDIs. Incongruent approaches within individual SDIs also significantly diminish the prospects for re-use of geospatial resources between SDIs.

1.3 Aim

The governance research presented in this thesis is motivated by the need to develop a common understanding of governance and the context within which it operates. Thus the aim of the research is to develop a model of SDI governance both to inform operational responses to identified real world challenges for SDI implementers and to further research into the role of governance in SDI.

1.4 Research objectives

In order to achieve the aims of the research project, the following research objectives have been defined:

1. Explore governance in a variety of contexts to review potentially applicable governance principles, theories and models for developing a conceptual framework for understanding SDI governance;
2. Evaluate recent research into SDI governance to determine current understandings;
3. Explore SDI governance challenges in practice, using a mixed method, case study based approach and extract from case studies common principles, patterns and critical elements that can be used to inform the development of an SDI governance model; and
4. Develop a model for SDI governance that articulates key governance concepts, processes and relationships.

1.5 Research design

The research design comprised four distinct steps, shown in Figure 1, below.

Step1 - Conceptual design

- Literature review – theory and practice in SDI and governance Review of documents from potential case studies
- Development of research approach and methods

2 SDI governance case studies

- Case study selection
- Design of data collection methods and tools
- Participant identification
- Data collection
- Analysis of case studies

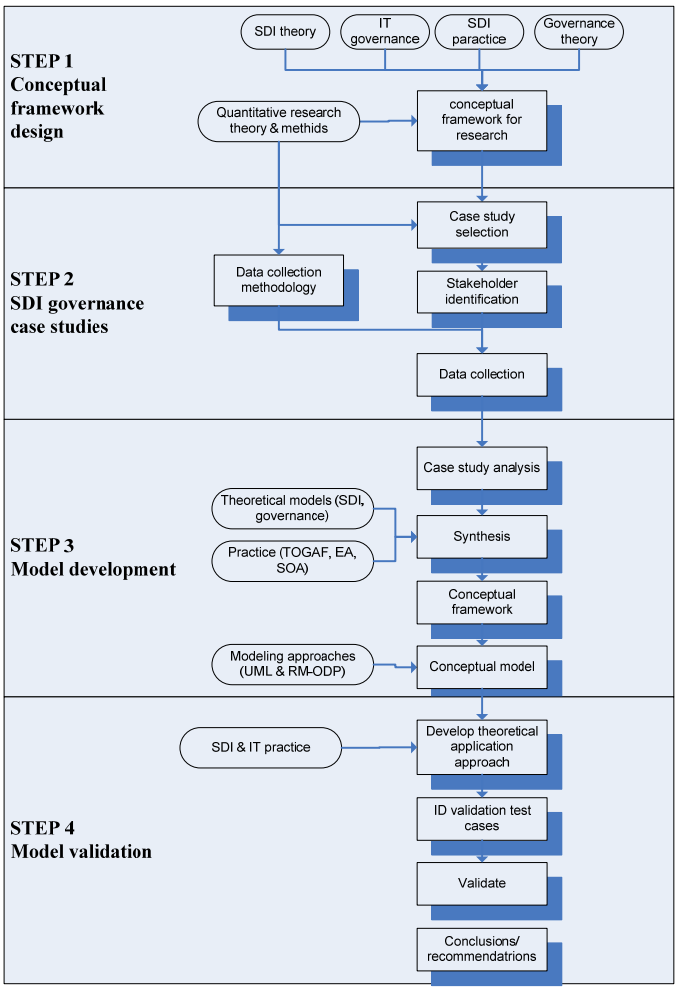

Figure 1 Research methodology

3 Model development

- Synthesis of findings with other models and theories identified in the literature Model development

4 Model validation

- Discussion of theoretical and practical application of the model

1.6 Thesis outline

The thesis is presented in three sections. The first, comprising chapters 2 to 4, presents a review of the literature related to SDI and governance. Chapter 2 provides a review of SDI research to date and highlights some emerging themes from practice that have significant governance implications. Chapter 3 contains a review of governance literature across disciplines to explore meanings, theories and models of governance. An

understanding of governance from this review is used as a conceptual framework for exploration of SDI governance in chapter 4. Chapter 4 thus explores SDI governance in literature and practice, which in turn is used to sharpen the focus of the case study research and to provide a map of the problem space to enable the conceptual placement of the model.

The second section of the thesis comprising chapter 5 describes the case study research developed in response to the gaps in knowledge identified in the preceding chapters. Chapter 5 describes the research rationale, design and methodology, together with a description of the case studies. The chapter then presents case study research findings together with an interpretation and analysis of the results.

The final section, comprising chapters 6, 7 and 8, presents the SDI governance model (6), a discussion of key aspects of the model and its application in theory and practice (7), and offers some conclusions and pointers for future research (8).

2. Spatial Data Infrastructure

2.1 Chapter overview

This chapter presents the evolution of the Spatial Data Infrastructure (SDI) concept, providing an overview of current SDI theories, their evolution and the perspectives that underpin them. A brief review of formal SDI modelling efforts is provided. The chapter then presents issues emerging from SDI implementation practice that are relevant from a governance perspective. The perspectives from SDI research and practice are then used to propose a working definition of SDI together with a description of key concepts that inform approaches to governance.

2.2 Introduction

Efforts to develop SDIs from sub-national to global levels have been underway since the early 1990s (Masser 2005). Efforts to-date have focused on addressing challenges related to sharing information within the context of a single SDI with limited efforts on addressing interoperability between SDIs. INSPIRE is a rare example of one such initiative (European Parliament 2007). However, the promised benefits of SDI have not yet been realised (Budhathoki and Nedovic-Budic 2006). For instance, an assessment of national clearinghouses for spatial data found an increase in the number but decline in the use, management and content of national clearinghouses between 2000 and 2002 Crompvoets et al. (2004) posited that this could be due to the dissatisfaction of users with the functional capability of the clearinghouses and the SDIs of which they formed a part.

2.3 SDI – an evolving concept

The concept of SDI can be viewed from a number of different disciplinary, cultural and technical perspectives. Coleman and McLaughlin (1998) for instance, identify five possible perspectives from which an SDI could be viewed - data, technology, institutional, market and application driven views. As noted by Budhathoki and Nedovic-Budic (2006), the lack of consensus on the elements and principles of SDI

resulting from the complex nature of SDI and the wide diversity of viewpoints hampers the development of SDI and associated research efforts.

Compounding the contested nature of SDIs is the fact that the concept is evolving. Masser (2005) traces the *naissance* of the SDI concept to several key events related to recognition of the need for and creation of bodies to achieve coordination of spatial data commencing in the late 1980's in Australia and the UK through to the defining/development of a national SDI in the US in 1993.

Development of national SDIs from the mid 1980s to 2000 has been classified by Rajabifard et al. (2003) as the 'first generation' of national SDIs. These initiatives were typically nationally-focused, driven by the need for integration of existing data, involving the participation of data providers and coordinated by national mapping agencies.

Around 2000, the early innovators involved in developing the SDI concept re-focused their efforts and redefined SDI conceptual models and strategies. This shift in focus resulted in the creation of a global SDI community leading to an increase in SDI implementation efforts, characterised as the 'second generation' of national SDIs (Rajabifard, Feeney et al. 2003). The major conceptual shift characterising the second generation was the re-conceptualisation of SDI as a platform to link people to data, with participation from all sectors of the spatial community, coordinated by independent coordination bodies.

Several major elements of the re-conceptualisation of second generation SDI efforts are:

- The move from the product-oriented to process-oriented view of SDIs;
- The recognition of the hierarchical relationships between jurisdictional SDIs that form a national SDI;
- The view of SDI as a dynamic platform to enable people to access data; and
- The shift from a techno-centric to a socio-centric perspective.

Theories and models that address each of these contemporary conceptual elements of SDI are discussed below.

2.3.1 From product to process models of SDI

Two models, the product-based and the process-based model, have been proposed to characterise different types of SDIs based on their underlying aims (Rajabifard, Feeney et al. 2003). The product model (which characterises the first generation of national SDI) describes an SDI which has the primary aim of linking geospatial databases of respective administrative/jurisdictional levels. The process based model describes an SDI that aims to define a framework to facilitate the management of information resources. The second generation of SDI is characterised by a move from the product to process model. This shift is described by Masser (2006) as a change in emphasis from concerns of the producers to those of the users of spatial data.

2.3.2 SDI hierarchies

It has been recognised that SDI are hierarchically nested and inter-connected (Chan and Williamson 1999). The SDI hierarchy model has been further extended to offer two views of the nature of relationships between the hierarchical levels – an umbrella view and a building block view (Rajabifard, Williamson et al. 2000). In the umbrella view, the higher level SDI comprises the enabling components, such as institutional framework, human resources, standards and access network that support sharing of data held by lower level constituent SDIs. This is a "top down" institutional perspective of SDI hierarchy as higher levels cover lower levels. In the building block view, SDIs at lower levels act as building blocks, providing geo-spatial data required by SDIs situated at higher levels of the hierarchy. This "bottom-up", "data-centric" perspective of SDI hierarchy emphasises the notion of SDI as a data sharing partnership.

Hierarchical spatial reasoning further extends the theory of hierarchical SDI by attempting to represent the horizontal as well as vertical relationships between each hierarchical level (Rajabifard, Escobar et al. 2000).

Central to hierarchical SDI models is the objective of enabling geospatial exchange and re-use between SDIs both horizontally (with SDIs on the same level) and vertically (with SDIs at higher and lower levels).

According to the theory of hierarchical spatial reasoning and its philosophical foundations in the work of Koestler (1967), an SDI is a *holon* i.e. something that is both a whole (i.e. an SDI in its own right) and a part (a sub-SDI within an SDI at a higher level of the hierarchy). From this perspective, governance of an SDI comprises the governance of the whole and the governance of the parts.

In order to realise the vision of geospatial data re-use between SDIs, there is a strong demand for semantic interoperability of geospatial services and data between SDIs. This will in turn lead to increased emphasis on the development of compatible architecture, standards and technology between SDIs, enabling the seamless exchange of spatial information and related semantic, which will require common approaches to governance both within and between SDIs.

2.3.3 Multi-level SDI implementation

Associated with the recognition of hierarchical relationships between SDIs is the notion of multi-level SDI implementation (Masser 2005). SDI initiatives tend to be implemented concurrently at multiple levels of the SDI hierarchy under varying degrees of coordination and governance. The reduced role of central governments in SDI implementation and the focus on creating a framework within which a national infrastructure can operate has led to a bottom-up, sub-national approach to SDI building (Masser, Rajabifard et al. 2008). In Australia, this is witnessed by the proliferation of SDI initiatives at State and local levels that are jurisdiction-wide, such as the Victorian Spatial Information Infrastructure, or that relate to an application domain, such as the Natural Resource Atlas (NRAtlas) in NSW. As noted by Masser, this approach results in "a collage of similar but often quite different elements that reflect the commitments and aspirations of the different sub-national government agencies" (2005, p.173).

2.3.4 A component view of SDI

Several authors have proposed a component based view of SDI comprising people policies, standards, technologies and data (Coleman and McLaughlin 1998, Rajabifard, Chan et al. 1999). Rajabifard et al. (2001) emphasise the dynamic nature of three of the SDI components - access networks, policies and standards that enable the interaction of the other two components, people and data. These components must adapt to changing technology and meet the evolving needs of people to access data as the SDI matures.

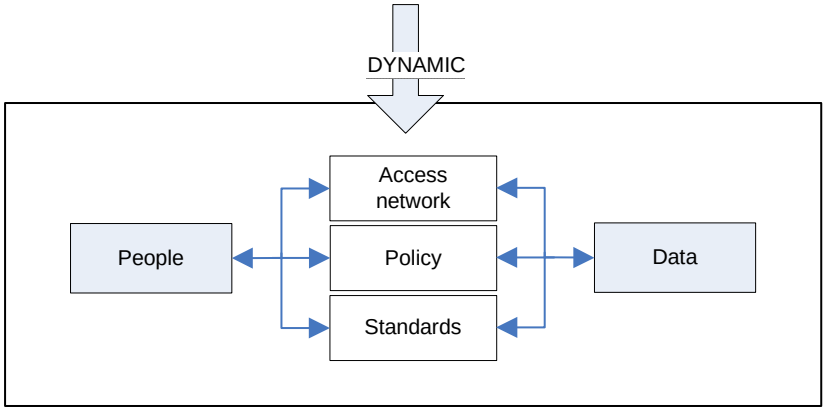

Figure 2 Relationship between key components of an SDI adapted from (Rajabifard and Williamson 2001)

2.3.5 The socio-technical perspective

Rajabifard et al. (2002) argue that SDI should be viewed from a socio-technical perspective, as successful SDI implementation is contingent upon resolving social (community) as well as technical barriers associated with implementation. This view is supported by Georgiadou et al. (2005) who argue that SDI research and practice focus almost excessively on geospatial information, resulting in the marginalization of the socio-political, historical and institutional dimensions of the SDI design and application.

The following sections provide a brief review of literature related to information infrastructure (II) theory which views information and other infrastructure through a socially-oriented lens and offers some interesting insights into the social dimensions of SDI, including governance.

2.3.5.1 SDI as an information infrastructure

In SDI literature there have been increasing calls to view SDIs as information infrastructures (II) and to thus draw on theoretical understanding of SDI that can be used to inform practice (Georgiadou, Puri et al. 2005, Budhathoki and Nedovic-Budic 2006, Aanestad, Monteiro et al. 2007). The premise of II theory is that individual information systems are an integrated part of large-scale networks rather than independent standalone systems. Large-scale networks are characterised by a socio-technical nature, dependence on standards, the dispersed incremental fashion in which

they evolve, and the role of the installed base from which they evolve (Aanestad, Monteiro et al. 2007). In addition, II theory recognizes that work routines and organisational roles are interwoven with information and technology that is being used within an infrastructure. Growing an II thus involves "enrolling actors through aligning their interests and practices" (Kok and van Loenen 2005, p. 15).

Hanseth (2002) defines an II as “a shared, evolving, open, standardized, and heterogeneous installed base”. He asserts that II, in common with other infrastructures, evolve over a long period of time, and are designed as extensions to existing infrastructures or “installed base”. The nature of the installed base influences the design of new elements and, as it grows, is self-reinforcing. For this reason, Hanseth argues that successful infrastructure requires cultivation chiefly through the creation of self-reinforcing processes and management of their direction.

A critical aspect of the self-reinforcement of the installed base is standards. Standards underpin information interoperability that is the driver for II creation. The installed base of an II is built around standards, but as the installed base grows with the implicit standards conformance, inertia builds around the standards as the cost and effort to change increases (Georgiadou, Puri et al. 2005). However, with the proliferation of standards and the inherent tension between flexibility and standardization (Hanseth, Monteiro et al. 1996), the development, adoption and application of standards is not straightforward. In fact, it is posited by Hanseth and Braa (2001) that the quest for standards, which are only universal as an abstract concept, is a utopian dream. This is due to the fact that when implemented, standards are locally-embedded in systems and practices, and are thus unique and not universal, and in addition are constantly changing in response to local conditions.

2.3.5.2 SDI as systems of systems and spatial cyber infrastructure

Several other perspectives on SDI that extend its conceptualisation as II have been proposed. Firstly, Béjar et al. (2009) propose that the last decade has seen the emergence of a type of system composed of other systems or System of Systems (SoS). The authors identify some shared characteristics of SoS and information infrastructure, namely their evolution, emergence, physical distribution and their networked and the

heterogeneous nature of systems. Building on this perspective, Béjar et al. (2012) modelled SDI as federated communities.

More recently, the literature references geospatial cyber infrastructure as a form of II. Harvey and Raskin (2011) propose that SDI is moving into a new era through the development of spatial cyber infrastructure while Diaz et al. (2011) put forward a bottom-up approach to implementing geospatial cyber infrastructure based around a service framework enabling *ad hoc* integration and deployment of geospatial data resources.

2.3.6 From a data-centric to a service-oriented view of SDI

Bernard and Craglia (2005) argue that a shift in understanding of SDI is required in order to better support and evaluate SDI implementation. The authors suggest that SDI should be viewed as an infrastructure to access and reuse services to answer specific questions, rather than as a network to find, view and exchange geospatial data. They also argue that the infrastructure should be used as a platform for sharing functionality encapsulated in a service and enabling the integration and chaining of services, rather than sharing just a platform for data (Bernard and Craglia 2005). In addition, Rajabifard el al. (2006) argue that the process of SDI development is a continuously evolving one with a continuum of development across all countries. They show a change from product to process-based model as an SDI continuum through the development of the first and second generations of SDIs which also includes the changing role that national government, sub-national government and the private sector play.

Underpinning this conceptual perspective of SDI is the wide-scale adoption of web services and the use of Service Oriented Architecture (SOA) approaches for SDI implementation. Web services and SOA are addressed again in section 2.5.3.

This viewpoint is consistent with the description of a Data Product in ISO 19131 – Geographic Information – Data Product Specifications (ISO 2008), which identifies that Data Products "support operations". Answering questions that may traverse the internal structure of the data, or even span references to related data sets can be implemented with services to avoid the user having to maintain complete copies of each data set. From this standpoint, data access is simply the most trivial of operations, so in effect the

service-oriented view is stating that SDI need to support more sophisticated agreements about behaviour of data to provide greater value. These agreements address more aspects of data product description, and require greater attention to providing a common semantic framework for describing the agreements. With more aspects to describe, more stakeholders are involved in the governance of the common models and terms required to describe each aspect, and hence governance of the common infrastructure components of an SDI rapidly emerges as the critical enabler to improve the value of the resources the SDI represents.

2.4 Formal SDI modelling efforts

There have been significant efforts to develop a formal model to describe and characterise SDI using UML by *inter alia* the International Cartographic Association (ICA) Commission on Spatial Data Standards (Cooper, Hjelmager et al. 2003, Cooper, Delgado et al. 2005, Cooper, Moellering et al. 2007, Hjelmager, Moellering et al. 2008, Cooper, Rapant et al. 2011). Formal UML models of other aspect of SDI have recently been developed. Béjar et al. (2012) model SDIs as federations of autonomous communities while Vaez and Rajabifard (2012) propose the use of formal UML model to design a seamless terrestrial and marine SDI.

To date, ICA modelling efforts have focused on articulating specific viewpoints as specified in the ISO Reference Model for Open Distributed Computing (RM-ODP). Models related to enterprise and information viewpoints (Cooper, Delgado et al. 2005) and the computation viewpoints of SDI (Cooper, Moellering et al. 2007). More recently, this model has been extended to include Volunteered Geographic Information (VGI) within SDI (Cooper, Rapant et al. 2011). High level use cases articulated in the enterprise viewpoint by Cooper et al. (2005) reproduced in Figure 3 below, have been developed. It is worth noting that all of these use cases have a governance dimension.

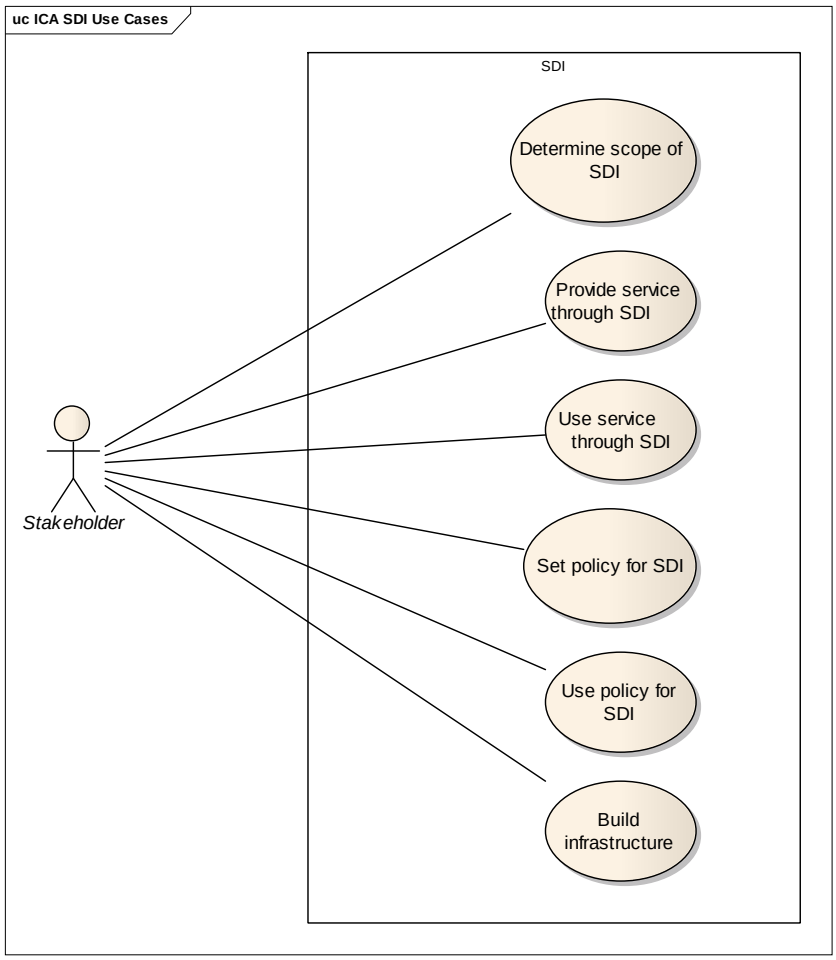

Figure 3 SDI use cases (Cooper, Delgado et al. 2005, p.3)

2.5 SDI implementation realities

SDI practice reflects the diverse technical, political, socio-cultural, organisational, legal, fiscal and business environments within which it evolves. Localised characteristics of an SDI, its position in the SDI hierarchy, and its conceptual and technical relationship with higher and lower-level SDIs, influence how an SDI is conceived and implemented. However, there are a number of issues emerging from SDI implementation practice (underpinned by theory and research) that are relevant from a governance perspective. The following sections review key SDI implementation issues with significant governance dimensions.

2.5.1 Custodianship

Custodianship of information is both conceptually and practically at the heart of SDI (Coleman and McLaughlin 1998, Rajabifard, Chan et al. 1999, Rajabifard, Feeney et al.

2002, Masser 2005, Hjelmager, Moellering et al. 2008, Béjar, Latre et al. 2012). Custodianship represents an assigned and accepted responsibility for an organization to collect, manage and provide access to an authoritative source of geospatial resources. The custodian effectively holds the resources in trust for the community and acts in the community interest to ensure that the resources are maintained, managed and accessible in accordance with community needs.

In the Australian SDI context, the principle of custodianship was initially articulated in the Guidelines for Custodianship developed in 1998 by the Australia New Zealand Land Information Council (ANZLIC) (ANZLIC 1998). These principles have been adopted and implemented at state and territory levels in Australia, for example in the Victoria Spatial Information Custodianship Guidelines (Victorian Spatial Council 2006) and the Western Australia Land Information System Data Custodianship Policy (Western Australia Land Information System Office 2006).

However, to act as a custodian requires a commitment to allocate organizational resources to meet the needs of other agencies and users that may be beyond the core business objectives of the organization. Approval to act as a custodian is required from organizational management. When geospatial resources are being delivered via services, such as web services, approval and operational support from an organization's IT functions is also required. However, there are several potential barriers to this happening. These barriers may result from the organization's culture, policy, or business model related to information sharing. In addition, given the relative newness of SOA and the risks and costs associated with its adoption, investments in services may be hard to justify, particularly when benefits largely accrue to those outside of the organization.

In many cases, an organisation's geospatial IT resources are treated as a special kind of IT resource and are not fully under corporate IT governance. The disconnect between an organisation's geospatial business units and its IT governance, may present a significant obstacle to acting as custodian.

With the emergence of volunteered Geographic Information (VGI) and crowd-sourcing, as important sources of information that can potentially be used to supplement and improve the quality of formal geospatial information, custodianship of these resources has become an even greater challenge (Gould, Craglia et al. 2008, Elwood 2010, Cooper, Coetzee et al. 2011, Díaz, Granell et al. 2011, Elwood, Goodchild et al. 2012). However, VGI is not considered further in this thesis as the focus is on formal geospatial information resources and this subject is dealt with comprehensively by other authors.

2.5.2 Top-down and bottom-up approaches to SDI

Two opposing views of SDI implementation approaches have been posited namely, top-down and bottom-up (Rajabifard, Feeney et al. 2002, Masser 2005, Carrera and Hewitt 2006, Masser, Rajabifard et al. 2008). The tensions between these two approaches are described by Masser (2005) as the conflicting needs for standardisation and uniformity and the need to accommodate diversity and heterogeneity of SDI stakeholders, their needs and capabilities. The top-down approach is characterised as a rigid, structured, directive-based approach driven by and imposed from above. However, top-down approaches do not preclude inclusive community participation in decision making processes *per se.* This is in contrast with the bottom-up approach, which is an organic, community-based, innovative, and largely technology driven approach to SDI implementation.

Both approaches have advantages and disadvantages and are suited to different contexts and situations, and there is a need to reconcile the two approaches so that SDI hierarchies can be built form top and bottom. A 'middle-out' approach that integrates top-down and bottom-up frameworks and applies each as appropriate is necessary to reconcile the different implementation approaches. In the case of Municipal SDI for example, Carrera and Hewitt (2006) advocate a middle-out approach that integrates a top-down approach to standards, with a bottom-up approach to data generation. As noted by Kok & van Loenen (2005) with reference to NSDI development in the Netherlands, SDI development in that country was partly planned and partly organic. Evidence from practice therefore suggests that a flexible approach specific to local realities should be adopted.

2.5.3 Service-oriented spatial data infrastructures

As has been noted by a number of authors, geospatial web services have been widely adopted as an approach to SDI implementation (Bernard and Craglia 2005, Finney 2007, Nebert, Reed et al. 2007, Béjar, Latre et al. 2009, Granell, Díaz et al. 2010, Schäffer, Baranski et al. 2010). This is witnessed by the increasing number of service-oriented SDI being developed at regional, national and local levels. Examples include INSPIRE (European Parliament 2007), GeoConnections (GeoConnections Secretariat 2010), the Indian National SDI (Singh 2009) and InaSDI, the Indonesian National SDI (Karsidi 2012). At sub-national level in Australian examples include the Western Australia Shared Land Information Platform (SLIP) (Western Australian Land Information Authority 2007), and the Spatial Information Services Stack (SISS) an open source geospatial service-based technology stack, widely used in Australia to build SDIs (Golodoniuc, Rankine et al. 2012). As this research focuses on governance of SDI developed using Service Oriented Architectures (SOA) an architectural approach to the design and maintenance of systems built from services, this section provides a brief introduction to SOA.

Josuttis (2007 p. 24) defines SOA as “an architectural paradigm for dealing with business processes distributed over a large landscape of existing and new heterogeneous systems that are under the control of different owners". It is worth noting that the definition indicates that the SOA approach is oriented towards dealing with systems that are distributed, heterogeneous, existing and yet to be built, and under the control of different business units and organisations. As this accurately describes the existing geospatial systems landscape and the challenge facing SDI implementation, it is obvious why SOA is becoming an increasingly common approach to architecting SDI.

The SOA approach is based on the design of services. Conceptually services are “a logical representation of a repeatable business activity that has a specified outcome” (The Open Group 2007 p. 6). The SOA approach aims to develop and maintain interoperable services that are a modular, self-contained set of functions that support a specific business process. These services are made available over a network, and are able to communicate and interact with each other via interfaces by passing data from one service to another.

Central to the operation of an SOA is the 'publish, find, bind' pattern shown in Figure 4 below. This pattern provides a mechanism for the publication, discovery and use of services in a service-oriented architecture, and comprises the following elements:

- A service provider advertises to a broker the availability of services and data by publishing metadata that describes its capabilities to a registry or catalogue;
- A service requestor is able to search metadata in the registry to find a specific type of instance of a service; and
- The service requestor is then able to directly bind to, or invoke the service using information contained in the service metadata.

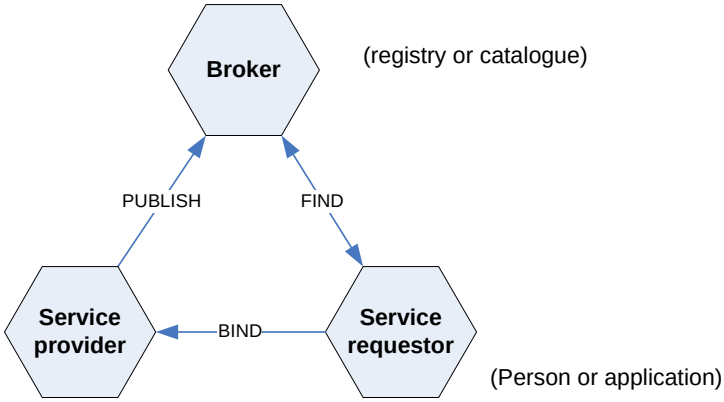

Figure 4 The publish, find bind pattern

Although the SOA approach is designed to be neutral of a specific technology platform, in reality the majority of services being developed in the geospatial and other domains are developed using the internet as the technology platform, and are thus referred to as web services.

In order to ensure that web services are interoperable and able to communicate with each other, and with applications, standard interfaces are required. In the geospatial area, the Open Geospatial Consortium[1] (OGC), a consensus-based geospatial industry

[1] www.opengeospatial.org

consortium, is developing service interface standards. The open (available at no cost) abstract and implementation interface standards developed by the OGC enable geospatial software developers to build support for standard interfaces into their products, and thus achieve interoperability between software via service.

2.5.4 SDI standards

Standards are at the core of SDI, and a range of geospatial and other standards are required to enable interoperability between components within an SDI. The core standards for SDI implementation are those developed by the Open Geospatial Consortium. These standards enable the interoperation of services (and their information content) within an SDI that enable the publication, discovery and use of geospatial web services to access, process and integrate geospatial data. However, as noted by Nebert et al. (2007) the proliferation of new standards, and new versions of old standards, creates many problems regarding the compatibility of standards within individual SDI initiatives. In addition, many SDI initiatives are developing their own standards in independent 'silos' that limit potential for interoperation between components of different SDIs. For this reason Nebert et al. (2007) have proposed the concept of an SDI standards suite 'SDI 1.0'.

Underpinning and supporting the OGC interface standards that seek to enable the interoperation of services within an SDI, are a range of other standards being developed by international bodies, such as the International Standards Organisation (ISO) and the Organization for the Advancement of Structured Information Standards (OASIS). The ISO Technical Committee 211 is developing a suite of standards (the 19100 series) for digital geographic information and the OGC standards are based this underlying framework of ISO 19100 series standards (ISO/TC 211 2010). OASIS, a not-for-profit consortium, is behind the development and adoption of open standards for related web services, such as the Extensible Markup Language (XML) which are foundational elements for OGC.

In addition to these international standards initiatives addressing digital geographic information and technical standards that underpin web services, data content standards, data models and application schemas for different application domains are being developed in parallel and in an often uncoordinated manner at international, national,

sub-national and enterprise levels. At the implementation level the proliferation of multiple potentially applicable standards creates confusion and an additional compliance workload for data custodians who wish to publish geospatial information using web services.

2.6 SDI definition

Although there are multiple definitions and models of SDI and differences in SDI implementation due to the conceptual perspectives and practical realities that shape them, there is a common underlying SDI objective implicit or explicit in all of these perspectives. This is described by Rajabifard et al. (1999) as that of providing an environment in which stakeholders can cooperate in an efficient and cost-effective way to better achieve their common objectives.

The following definition of SDI will be used as the basis for exploration of SDI governance in the following chapter:

> *'A spatial data infrastructure is a collaborative, agreement-based approach to the creation, maintenance, provision and use of distributed heterogeneous geospatial resources under heterogeneous ownership and operation working collectively to meet common information needs to address real world challenges.'*

Two key elements of the definition that are of critical significance in the context of SDI governance are:

Geospatial resources - Central to all SDI models is the premise of geospatial information exchange and re-use within an SDI as well as between SDIs in an SDI hierarchy. However, geospatial information is one kind of 'geospatial resource' that comprises an SDI. The services, applications, support tools, collaborative environments, workflows, processes, documented knowledge of the SDI community that underpin discovery, access and use of information resources, also are considered to be 'geospatial resources'. Geospatial resources are the central component of any SDI and can be both

individually and collectively owned and operated on behalf of a community, to meet collective goals.

Heterogeneous ownership and operation - SDI is a collaborative endeavor involving multiple stakeholders. Geospatial resources are typically under the heterogeneous ownership and operation of often significant numbers of organizations each with heterogeneous social and technical characteristics. Organization are typically embedded within one or more territorial jurisdictional (regional, national, or sub-national) as well participating in a range of technical and thematic governance frameworks such as natural environment, health, education or defense. This patchwork of jurisdictional and thematic collaborations with associated governance arrangements will shape the nature of geospatial resources.

Agreements - Agreements articulate the common understanding of the community with regard to the ends of the initiative and the means of achieving them. There are a significant number and form of agreements used in the context of SDI these include: policies, licenses, best practices, and typically a number of standards and specifications that guide many different aspects of geospatial resource creation and management. Agreements are elaborated to different levels of specificity that are determined by the interoperability targets set by the community.

SDI as an approach - The definition describes SDI as an approach to achieving an objective. In this context, governance plays a central role in achieving and maintaining consensus regarding collective interests through the alignment of individual interests. In addition, governance should attempt to create an environment and conditions that encourage, foster and support the necessary changes in organizational and individual cultures and practices that are an inherent aspect of installed base. Furthermore, given the reality of multi-level SDI implementation, and the evident institutional and governance dependencies between SDIs, together with a requirement for interoperability between SDIs, it is critical that approaches to developing SDI addresses compatibility between SDIs.

2.7 Chapter summary

This chapter aimed to set the context for an exploration of SDI governance in a subsequent chapter. It has provided an overview of the continuing evolution of SDI theory and practice, highlighting key theories and models together with a brief examination of some critical implementation challenges that have significant governance implications. The evolving nature of the SDI concept and the important roles of SDI conceptualisation and the implementation context in shaping an SDI have also been highlighted. SDI will continue to be an evolving concept recast in accordance with latest developments in the geospatial world including, new architectural styles and approaches from the broader IT community, such as restful services and linked data and changing geospatial industry realities such as increasing role of private sector and Volunteered Geographic Information (VGI). The chapter concluded with a definition of SDI, highlighting critical concepts that form the foundation for the development of SDI governance model.

3. Governance

3.1 Chapter overview

The previous chapter discussed the evolving concept of SDI and highlighted several implementation issues with significant governance dimensions. This chapter explores the evolution and current understandings of the concept of governance in a number of inter-related contexts relevant to the consideration of SDI governance. Public governance provides a starting point as it represents the genesis of the concept. The chapter then briefly explores corporate governance, IT governance and project governance. These contexts are directly applicable to SDI governance as SDI touches multiple organisations, has an IT focus, and is typically implemented as a series of discrete projects.

The chapter concludes with a working definition of governance which, together with the chapter provides an overall theoretical map of governance, setting the scene for exploration of SDI governance in the subsequent chapters.

3.2 Introduction

In broad terms, governance is about collective decision making. Etymologically, the concept of governance comes from Greek *κυβερνάω,* which means either to steer or pilot a ship (Kjær 2004). Although the term governance was originally used to describe the act and capabilities of government to govern i.e. to make and administer public policy of a political unit, governance can in fact operate as a collective activity of any scale, from several people to the global level. The Commission on Global Governance (1995 p.2) defines governance as:

> *"the sum of many ways in which individuals, institutions, public and private, manage their common affairs. It is the continuing process through which conflicting or diverse interests maybe accommodated and cooperative action taken".*

Today, governance is a key concept in a variety of disciplines and professions. However, governance means different things to different audiences and its meaning, scope, tasks and functions are dependent upon the context in which it is being used. In order to develop robust scalable approaches to SDI governance, it is necessary to develop a sound theoretical understanding of governance. To this end, following is a review of contemporary theories of governance in the spheres of public, organisational, technology and project governance.

3.3 Public governance

The term 'public governance' relates to the political sciences, and notably the sub-disciplines of public administration and policy, international relations, integration studies and comparative politics, in which there are a number of theoretical debates about governance, or how societies are governed.

Governing societies can be viewed from two interrelated viewpoints. From a singular perspective, it relates to the governance of the internal, domestic affairs of a political state, and from the plural perspective, to the governance of a system or number of political units in the international domain through the use of laws, international organisations and alliances (Mitchell 2004). The former is covered by the study of domestic politics and the latter the study of international relations. However, as will be shown in this chapter the distinctions between domestic governance and international relations are becoming increasingly blurred as new forms of governance have developed in response to changing socio-economic and political realities.

3.3.1 Public administration and public policy

3.3.1.1 Political governance

Governance, or the act of governing, was traditionally considered to be the sole responsibility of government, using top-down hierarchical, bureaucratic structures based on Weberian principles (Weber 1978). The World Bank (1991) reflects this government-centric view in its description of governance which encompasses:

- the form of political regime;

- the process by which authority is exercised in the management of a country's economic and social resources; and
- the capacity of government to design and implement policies and discharge its function.

In democracies governance exercised by government is conceptual, underpinned by the 'parliamentary governance chain' (Olsen 1978) shown in Figure 5, This chain is underpinned by the concept of separation of power between three branches of government, the executive, legislative and judicial and emphasises the distinction between the policy making functions of executive and the implementation function exercised by civil service. In this model, political authority is vested in the sovereign people and exercised through officials elected by the people, organised around a legislative assembly responsible for determining common interests and overseeing the government's implementation of its decisions. The government (executive branch) introduces policies to parliament for decision and the civil service is the administrative apparatus of government responsible for implementing the goals set by the executive.

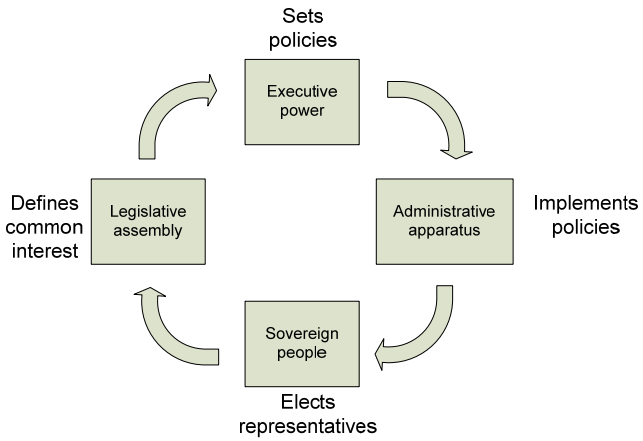

Figure 5 Parliamentary governance chain

Adapted from (Kjær 2004) based on (Olsen 1978) (Olsen, 1978)

The following sections explore changes that have taken place in the public sector largely in response to changing socio-political and technological realities. These changes have led to a great deal of discourse in the field of public administration about

the meaning and nature of governance and the changing role of government in governance.

3.3.1.2 Public sector reform

In many western liberal democracies, the period between the 1950-1970s witnessed an expansion of the state from a regulatory authority that provided basic infrastructure, to a provider of social services (Kjær 2004). By the 1970s, it was argued that the traditional, rigid, hierarchical, bureaucratic structures of government were not well suited to deliver social services, where a more responsive client-focused approach was required, particularly at the 'street-level' interface between government and citizen (Lipsky 1980). Osborne & Gaebler (1993) argued that government bureaucracies were not able to effectively deliver services, and thus should focus on policy setting or "steering" rather than service delivery or "rowing". Consequently the 1980s and 1990s saw major public sector reforms, focusing on privatisation, enabling increased citizen participation in public affairs, and decentralisation of policy implementation and, in some cases, policy making.

The first major area of reform was privatisation of service provision, with the sale of public sector assets to the private sector together with outsourcing in which the state continues to fund but contacts out the provision of services. As a result of privatisation of service provision, "regulation replaced ownership as the preferred form of public intervention" (Rhodes 1996 p. 654). Growing demands from citizens to participate in public affairs led to a variety of reforms aimed at empowering citizens, including the creation of more channels for participation (e.g. referenda), as well as the movement of decision-making closer to citizens (Bogason and Musso 2006).

Another major area of reform, driven by the desire to make decision-making more responsive to the needs of citizens, was decentralisation of central government functions to lower levels of government through devolution or de-concentration (Kjær 2004, Marks and Hooghe 2004).

3.3.1.3 Consequences of reform

Privatization and decentralisation led to a smaller, 'hollowed out', and fragmented public services (Rhodes 1996 p. 661) resulting in concerns about fragmentation,

steering and accountability. As service design and delivery was increasingly undertaken by the private sector and civil society, a whole range of new actors and organisations became stakeholders in the decision-making process, and there was a blurring of the line between state and civil society. Collaborative approaches to designing and delivering services involving both the users and those involved in service delivery have also gained prominence (Bovaird 2005). These 'co-production' approaches recognize that policy is no longer a top-down specification from government, but the result of negotiation between interacting policy systems. In addition, the important role of service users in shaping service outcomes has been recognized.

3.3.2 New modes and models of governance

Governance is and will continue to be a contested and evolving concept in the political sciences. However, there is an underlying theme in the literature relating to the increasingly participatory nature of governance enabled through new modes of governance which is explored in this section.

Since the 1990's governance literature has focused on non-hierarchical governance structures and the participation of non-state actors in public policy creation and implementation. New modes of governance were identified as alternatives to hierarchical top down government structure (Rhodes 1996, Rosenau PV 2000, Héritier and Lehmkuhl 2008). Rosenau (1992) characterises the role of government in governance as being one of mandate backed by formal authority. He compares this to a broader notion of more participatory governance which is driven by motivation and backed by shared goals. Rhodes (1996) asserts that hierarchical governmental models of governance are outmoded as governance is concerned primarily with managing 'policy networks', while the role of government is one of enabling socio-political interaction and encouraging innovation to respond to service delivery challenges. However, as noted by Kjær (2004) hierarchical and network governance models co-exist as the former is still the model upon which political representation is based and policies still need to be approved by elected bodies.

Recognising the existence of various modes of governance, Boviard defines governance broadly as "the ways in which stakeholders interact with each other in order to influence the outcomes of public policies" (2005 p. 220). This definition is extended by Dean

who asserts that governance can be viewed "less as the intended action of a particular agent (the government) on an object (society) but more as an overall strategic set of relations which are facilitated and coordinated by various regulatory agencies" (2007 p. 9). This interpretation is useful as it views governance as the relations between actors coordinated by regulatory agencies assists in conceptually reconciling the hierarchical and heterarchical governance models both of which are varying forms of network relationships.

Smismans (2008) characterises the non-hierarchical 'new governance' models as 'heterarchical'. This term initially was used to describe cognitive structures in the human brain that though orderly are not hierarchical (McCulloch 1945). Heterarchical structures are considered to be unranked with complex, duplicate and overlapping relationships.

It is generally accepted that critical challenges of governance relate to the steering of policy networks (Rhodes 1996, Kjær 2003). As noted by Kjær (2004) the importance of networks in service delivery does not mean less government but instead presents new challenges to government actors requiring a coordinator, often from government, to steer networks. This reality is characterised in the governance literature as the 'shadow of hierarchy' that is cast over heterarchical governance (Héritier and Lehmkuhl 2008, Börzel 2010, Héritier and Rhodes 2011)

The following sections provide an overview of governance in the domain of international relations in the context of globalization and within the European Union where Multi-Level Governance (MLG) has emerged as an important perspective on interacting modes of governance operating across scale of government.

3.3.2.1 Globalisation and international relations

The field of international relations has long been considered to be the study of inter-governmental relations (Kjær 2003). The traditional neo-realist perspective of international relations views the international arena as being a system comprising states that are equal, unitary, rational in pursuit of national security interests, and that seek to increase their relative capabilities (Waltz 1979). The system within which states interact

is anarchic, lacking a higher authority to govern it (Kjær 2004) and thus, states are in constant readiness for war.

Liberalists have challenged the neo-realist view based on the realities of globalization (Kjær 2004). Liberalists assert that the involvement of non-state actors in international relations, including transnational corporations, international organizations and civil society, together with the multiplicity of flows of goods, people and information across borders, challenge the unitary, rational behavior of states (Keohane and Nye 2001). Keohane and Nye (2001) also assert that mutual dependence between states may preclude the use of force in dispute resolution thus increasing the importance of using economic and other resources as foreign policy instruments.

Held and McGrew characterise globalisation as "the expanding scale growing magnitude, speeding up and deepening impact of interregional flows and patterns of social interaction" (2003 p. 4). They further assert that the notional transformation of people from citizens of separate sovereign states to citizens of a 'global village' is enabled by advances in infrastructures, including physical infrastructure such as transport and IT, and normative infrastructure, such as regulatory frameworks.

Phenomena such as climate change or the Global Financial Crisis demonstrate that distant actions can have major consequences close to home. The realization that humanity is economically, technically, ecologically, socially and politically connected and that the scale of the problems, and thus the solutions, transcend national borders, has led to recognition that some form of global governance is required. Although there is lack of agreement about the form of global governance, there is general consensus that the concept does not imply world government or global federalism (Commission on Global Governance 1995). Rosenau conceives global governance "to include systems of rule at all levels of human activity from the family to the international organization – in which pursuit of goals through the exercise of control has transnational repercussions" (1995 p. 13). This all-encompassing vision of global governance highlights the interconnectedness of governance systems at sub-national, national and supra-national levels. Weiss (2000 p. 808) suggests that global governance should be viewed as a heuristic device to assist in understanding "the confusing and seemingly ever

accelerating transformations of the international system". He goes on to assert that from this perspective, states are important but their authority is eroding, and the bodies created by them - international organisations – are still not effective actors in global governance.

3.3.2.2 Multi-level governance, open method of coordination and comitology

Integration of member states in the European Union (EU) has given rise to the theory of multi-level governance (MLG), a term first used to describe developments in EU structural policy in late 1980s (Flinders and Bache 2004). Since then, the concept of MLG has evolved to describe and explain the policy decision-making process in the EU (Marks 1993, Bache and Flinders 2004, Flinders and Bache 2004, Marks and Hooghe 2004, Bovaird 2005, Newig and Fritsch 2009, Hassel 2010, Héritier 2010, Piattoni 2010, Duda 2012).

EU integration, in parallel with de-concentration and decentralization in Member States, resulted in the dispersion of national authority upwards to supranational and downwards to sub-national level (Marks and Hooghe 2004). The increased capability and autonomy of local government and its reliance on supranational and international, rather than national, funding reduced the operational and fiscal role of central government (Peters and Pierre 2004). The result is a multi-level governance environment that is a "system of continuous negotiation among nested governments at several territorial levels" (Marks 1993 p. 392) with tiers of government at local, national and supranational levels involved in "territorially overarching policy networks" (Marks 1993 p. 402-403).

MLG implies interactions vertically (between levels of government) and horizontally (between government and non-government actors), at each level (Flinders and Bache 2004). However, although levels of government are embedded within a hierarchical structure with attendant rules and coordination mechanisms, this does not preclude them from pursuing their own interests in other fora. These interests typically relate to production of public goods created via co-production; which transcends levels of Europe's governance (Héritier and Rhodes 2011).

Marks and Hooghe (2004) identify two conceptual approaches to MLG called Type I and Type II. Type I is conceptually similar to the federal model, in which authority is dispersed to a limited number of levels of general purpose, long-term jurisdictions that bundle multiple functions, including policy, with the lower levels contained within higher levels. Type II MLG is conceived as being specialised jurisdictions established to address specific issues, such as the provision of services or standards development. These jurisdictions are flexible, fluid, overlapping and are created and sustained in response to needs.

Examples of MLG within the EU include the Open Method of Coordination (OMC) and Comitology. OMG is a relatively new decentralised approach to intergovernmental governance that is being adopted in a number of policy areas in the EU. The OMC evolved out of policy processes that emerged in the EU throughout the 1990s, and was formally established by the Lisbon European Council in 2000 (Radaelli 2003). The OMC process is based on the development of broad policy goals at the EU level which are then used as guidelines for national and regional policies, the implementation of which are monitored using agreed indicators. The method does not use any formal enforcement mechanisms, but rather peer pressure is seen as a key compliance driver (Borrás and Jacobsson 2004, Borrás and Radaelli 2009).

Comitology refers to a process by which EU law is modified or adjusted. The process takes place within comitology committees that enable discourse between the EU and its member states prior to introduction of legislation (European Union 2012) is another expression of MLG. Committees that facilitate discourse are created by the European Commission which is responsible for implementing legislation enacted by the European Parliament and the EU Council. It is worth noting that one of the key governance mechanisms that underpins the Infrastructure for Spatial Information for Europe (INSPIRE), a pan European SDI initiative, is the comitology process (Vandenbroucke, Zambon et al. 2008).

Marks and Hooghe (2004) assert that the dispersion of governance across multiple jurisdictions is more efficient than a centralised governance monopoly and that governance must operate at multiple scales to respond effectively to, and thus internalise, the variation in "territorial reach of policy externalities" (Marks and Hooghe

2004 p. 16). Thus, different levels of governance are most effective at addressing policy issues that reflect the scope of a particular issue. For instance, global governance is required to tackle global scale issues, such as climate change, while local governance is more appropriate to respond to local issues, such as transportation. In an analysis of the impact of multiple levels of governance on outcomes of participatory decision-making to deliver environmental policy output and to improve implementation and compliance Newig et al. (2009) provide compelling evidence of improvements in environmental policy as a result of decision-making on multiple levels. However, Smismans (2008) asserts that the new modes of heterarchical governance such as those found within MLG environments do not necessarily lead to more inclusive participatory decision making.

3.3.3 Accountability and the service provision model

Accountability is a concept that underpins governance and enables citizens to delegate authority to elected officials (through electoral processes) to run a polity. The elected officials set policy and delegate responsibility for delivery of services to achieve policy objectives to service delivery organisations. These organisations in turn deliver services to citizens. The World Bank developed a model that describes this service delivery framework or chain, based around the actors involved in service design, delivery and consumption, and the key features of the accountability relationship between them (The World Bank 2003). This model, shown in Figure 6, describes five features of accountability that characterise the relationship between actors involved in service design, delivery and use. These features are delegation, finance, performance, information about performance, and enforceability.

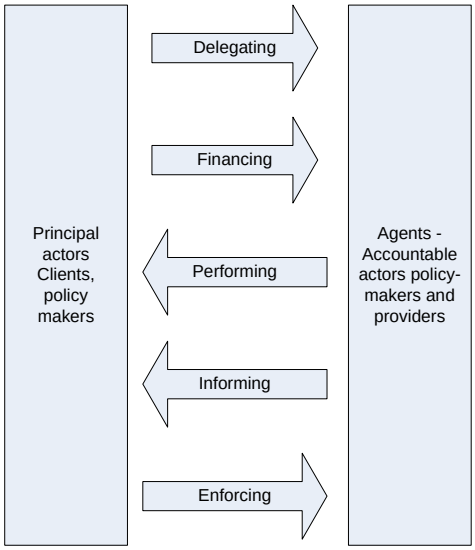

Figure 6 Five key elements of the accountability relationship adapted from (The World Bank 2003 p. 47)

The actors engaged in interaction within this accountability framework are:

- Citizens who elect politicians/policy-makers;
- Politicians/policy-makers who create policies and make arrangements for provision of services;
- Service providers (organisations and the people within them with whom the clients interact) that provide services that implement policies; and
- Clients (or citizens) who use these services.

In this model, citizens and politicians/policy makers may take on the role of principle actors and politicians/policy makers and service providers may take on the role of agent, for example, citizens elect politicians/policy-makers and citizens consume services from service providers. This model, and the universal features of accountability that is posits, provides a useful conceptual framework for understanding the key relationships that are at the heart of SDI operation and its governance – namely, custodianship, individual representation in collective decision-making, and delegation.

3.3.4 Good governance

Since the 1990's in the field of human development, governance has become an increasingly important concept for the United Nations and international donors (Magel and Franke 2007) and good economic and political governance has become a condition

for development assistance (Weiss 2000). Consistent with the goals of promoting liberal democracy (Rhodes 1996), efforts have focused on assisting states to create governance systems that promote, support and sustain human development. This focus has led to the articulation of commonly accepted prescriptions for 'good governance'.

The United Nations Development Programme (UNDP) defines governance as, "the exercise of political, economic and administrative authority in the management of a country's affairs at all levels" (Undp 1997 p.2). In this context good governance is seen as being the development of structures and processes that guide the political and socio-economic relationships between the political, economic and administrative spheres of governance. Furthermore good governance ensures that political, social and economic priorities are based on broad consensus in society. In its report, UNDP identifies 10 characteristics of good governance:

- Participation - all should have a voice in decision-making;
- Rule of law - legal frameworks should be fair and enforced impartially;
- Transparency – based on the free flow of information;
- Responsiveness - institutions and processes try to serve all stakeholders;
- Consensus orientation – mediates differing interests to reach a broad consensus;
- Equity – equal opportunities to improve or maintain well-being;
- Effectiveness and efficiency - processes and institutions produce results that meet needs while making the best use of resources;
- Accountability - decision-makers are accountable to the public, as well as to institutional stakeholders; and
- Strategic vision - a broad, long-term perspective on achieving common goals.

It is worth noting that much has been written in the literature about the role of SDI and land administration in achieving good governance (Ting and Williamson 2000, Georgiadou, Rodriguez-Pabón et al. 2006, Williamson, Enemark et al. 2010, Bennett, Tambuwala et al. 2013).

3.4 Corporate governance

With the growing complexity of society and the creation of organisations that enable people to work together to achieve common goals, mechanisms to control and direct collective efforts have become increasingly important. Corporate governance which provides a means of governing organisations can be traced back to the creation of the first joint stock companies of the 17th century when for the first time companies' had legal identities separate from their owners and operators (Kakabadse, Bank et al. 2004). With the separation of ownership and management, it was necessary to create governance mechanisms to reconcile the interests of the owners and the management of a company.

The key and fairly ubiquitous components of the modern corporate governance model are a board, elected by the owners (or stakeholders in the case of public sector organisations) to represent their interests, and management led by a Chief Executive Officer (CEO) elected by the board. The board delegates authority to run the organization to the CEO and is responsible for management, accountability and supervision of the management. Bloem's definition of corporate governance as the "collection of formal and informal mechanisms that bring managerial behaviour in line with interests of company owners" (Bloem, Doorn et al. 2005 p. 8) emphasises the important function of balancing stakeholder interests in an organisation.

However, corporate scandals in the 1980s and 90s caused by weak governance and lack of accountability, particularly around financial reporting, led to calls for corporations to be more accountable to shareholders as well as to the regulatory systems in which they operated. Due to concerns about corporate financial accountability in the early 2000s, many countries introduced legislation, such as the Sarbanes Oxley act in the US, to tighten financial control, auditing and accountability of corporations (Bloem, Doorn et al. 2005). However, as the Global Financial Crisis of 2007-8, the most serious financial crisis since the Great Depression can to an important extent be attributed to failures and weaknesses in corporate governance arrangements (Kirkpatrick 2009), attempts to address weakness in corporate governance at least in financial institutions have met with limited success.

3.4.1 Public sector corporate governance

Reforms in the public sector including privatization, competitive tendering and the introduction of private sector management styles in the 1990s led to an increased awareness of the need for sound corporate governance of public sector bodies (CIPFA 1994, Kjær 2003). Concerns about the financial probity of public officers generated an interest in corporate governance of public sector bodies. Based upon the Cadbury report (Committee on the Financial Aspects of Corporate 1992) definition of corporate governance, the Chartered Institute of Public Finance and Accountancy (CIPFA) identified three fundamental principles for governance that applied to both public and private sector organisations (CIPFA 1994) namely:

- Openness (or disclosure of information);
- Integrity (or straightforward dealing) and completeness; and
- Accountability through clear assignment of roles and allocation of responsibilities.

3.5 IT governance

As organizations have grown, their IT resources have grown significantly often in an uncontrolled and chaotic manner with different business units being responsible for meeting their own IT needs. As a result, resources are often under the control of different owners (e.g. business and IT units) within an organisation that serve specific business functions. Consequently, there is little reuse of data or functions and multiple copies of the same data may be held by different departments entailing a major data management overhead. The need to bring these systems under control so that they may be integrated and maintained, has led to an increased interest in IT governance (Bloem, Doorn et al. 2005).

The IT Governance Institute (ITGI) takes a very broad view of IT governance encompassing "the leadership and organizational structures and processes that ensure that the organisation's IT sustains and extends the organisation's strategies and objectives" (2007 p. 10). IT governance typically occurs within the context of corporate governance, and although governance functions are the responsibility of the board, governance activities need to occur at every level of an organisation. Figure 7 presents

the IT governance process as articulated by the IT Governance Institute, with the starting point being objective setting and providing initial direction. A continuous loop comprising implementation of IT activities, measurement of performance and comparison with (and if necessary redefinition of) objective, is then established. Setting and revising strategic objective is the responsibility of the board, while management is responsible for conducting IT activities, performance measurement and reporting to the board.

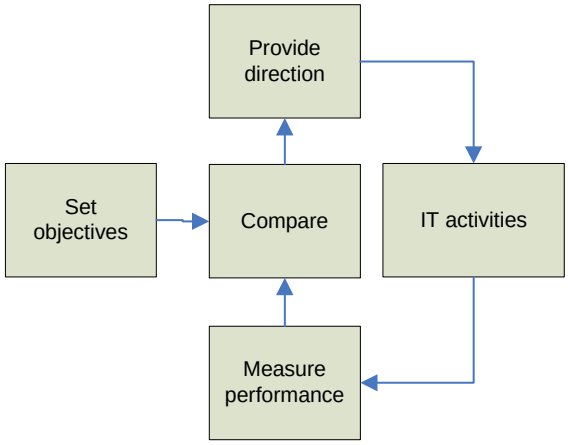

Figure 7 IT governance processes (IT Governance Institute (ITGI) 2007 p. 12)

The role of the board in this process is to ensure that IT strategy is aligned with business strategy, that it is leveraged to maximise business opportunities, that IT resources are used effectively and IT risks are managed, while the role of management is to focus on increasing automation, decrease costs and manage risk associated with IT.

There are a significant number of conceptual approaches, models, frameworks, standards and tools for IT governance. Although a detailed review of IT governance is beyond the scope of this research, the following sections review three specific approaches to governance of aspects of IT that are of relevance in the context of SDI governance:

- The IT decision rights framework that offers a narrow view of IT governance within the context of a single organisation;
- Enterprise Architecture (EA) governance to represent a more holistic approach to IT within multi-organisational contexts. This is considered to be of particular

relevance as EA is being increasingly used for whole-of-government IT initiatives, including SDI initiatives; and

- Service Oriented Architecture (SOA) governance. SOA is a style of EA and as it is the current technology paradigm for implementing SDI, SOA governance needs to be addressed within SDI governance efforts.

3.5.1 A decision rights framework

A narrow view of IT governance within an organisation is adopted by Weill and Ross who define IT governance as "specifying the decision rights and accountability framework to encourage desirable behaviour in using IT" (Weill and Ross 2004 p. 2) These authors developed an IT governance framework to enable assessment and improvement of existing IT governance. The framework includes three main components: 'domains', 'styles' and 'mechanisms'. Domains articulate five related areas of IT governance decisions as follows:

- IT principles - how will IT create business value;
- IT infrastructure strategies - how will shared services be built;
- IT architecture - what technical guidelines and standards will be used;
- Business applications - what applications are needed; and
- IT investment and prioritization - how much should be invested where.

The 'styles' component of the framework identifies stakeholders involved in the decision making process (decision inputs) and those with authority to make decisions. Styles are based on six 'political archetypes' (Clark 2005) which describe groups ranging from business and IT monarchies to federal, feudal, duopoly and anarchic archetypes. Groups and domains are presented in a matrix that is then is used to record who has input and authority to make decisions in each domain. Having identified the decision input and authority for each domain, the decision-making structure, and processes are documented. This enables an analysis of the complete IT governance approach. Based on this analysis, an organisation is able to rationalise the decisions input and authority together with governance mechanisms for each domain.

In a study of over 250 enterprises Weill and Ross (2009) report that organizations with superior IT governance report profits of 20% more than organizations with poor IT

governance. Literature provides example of the application of Weill and Ross's decision rights framework including; in the development of an enterprise level data governance framework (Khatri and Brown 2010) and allocation of IT decision rights in multi-business organizations (Reynolds, Thorogood et al. 2010).

3.5.2 Enterprise architecture and its governance

The Institute for Enterprise Architecture Development (2007) defines Enterprise Architecture (EA) as being "about understanding all of the different elements that go to make up the enterprise and how those elements interrelate". EA describes the entire process and practice of analysis and re-design of the structure and behaviour of an enterprise. There are many different EA frameworks and approaches in use; however, common to many is the sub-division of an enterprise into four elements: the business, applications, information and technology. These elements are often adapted for different purposes. For example, the Geospatial Profile of the US Federal Enterprise Architecture (US FEA) effectively re-packages the NSDI in a way that makes it compatible with other Federal enterprise architectures. It utilises five elements: performance, business, services, data and technology perspectives to address the NSDI concerns (Architecture and Infrastructure Committee Federal CIO Council and FGDC 2009).

3.5.2.1 The Open Group Architecture Framework (TOGAF)

One aspect of a widely used EA framework, The Open Group Architecture Framework (TOGAF) is worth exploring in more detail, as it specifically addresses enterprise architecture governance. TOGAF comprises a set of methods and tools for developing EA. Recognising the importance of governance as a critical aspect of re-engineering enterprises, an architecture governance framework was developed as a component of TOGAF (The Open Group 2006). Conceptually, TOGAF views architecture governance as an approach and a series of processes and owned responsibilities that aim to ensure the integrity of organisational architectures. Elements of the governance framework are presented in Figure 8. Key aspects of the model are: the context in which governance operates, architecture governance processes, the content (architectural artefacts) to be governed, process flow control to coordinate the application of processes, and the management of artefacts in a repository.

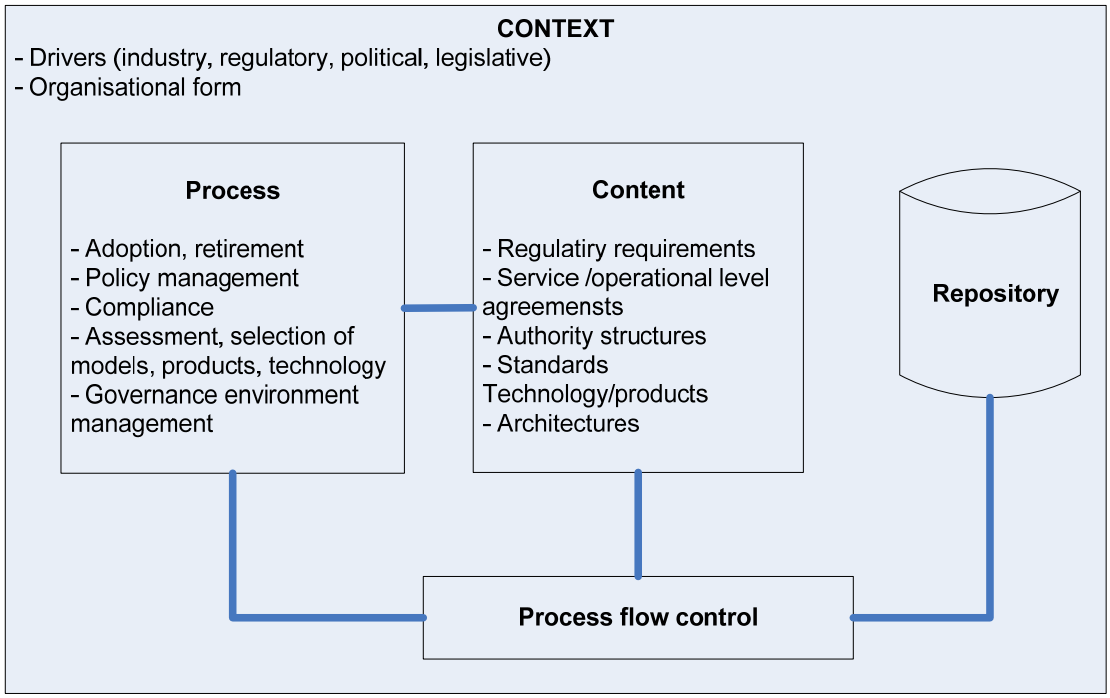

Figure 8: Architecture Governance Framework

Conceptual Structure (The Open Group 2006)

Elements to note with regard to the governance model are:

- The separation of the context and processes allow changes in legal, regulation or policy from the surrounding environment to be accommodated without impacting processes;
- The separation of process from content enables the articulation of common processes that can be applied to different types of content;
- The processes cover the formal take-on and retirement of architecture artefacts (such as models, specification, standards); compliance of capabilities with agreements; monitoring and reporting; and managing the governance environment including the registries and stakeholders; and
- The critical role of registries as a governance tool.

3.5.3 Service oriented architecture governance

As indicated in section 2.5.3, Service Oriented Architecture (SOA) is an architectural style based around discrete services that can be aggregated to create applications. Experience in the deployment and maintenance of production services has led to a

realisation that the environments within which services are developed, approved, published and discovered need to be coordinated and managed (Manes 2007). In the field of SDI, where there is less experience in deploying and operating production geospatial web services, although the need for SOA governance is acknowledged, the requirements for governance are not yet fully understood (Finney 2007).

SOA governance is concerned with control over services in an SOA and provides the business context for the design, development operation of services. However, in common with most other contexts, SOA governance has a multitude of different definitions and is a hot topic in the SOA world. SOA governance is responsible for determining what decisions are to be made, who is responsible for making them and setting policies for consistent decision-making (Woolf 2007). The focus on governance rather than on management reflects the challenging social and institutional, rather than technical, nature of decision-making activities and the need for collaborative, inclusive, participatory approaches to SOA. This in turn reflects the nature of services which are heterogeneous, distributed, and although under the control of different owners, interdependent. This interdependence necessitates collaboration between the owners, developers, operators, and users of the service across departmental and organisational boundaries (Josuttis 2007).

Oracle defines SOA governance as “an interaction between policies (what) decision makers (who) and processes (how) in order to ensure SOA success" (Oracle 2007 p. 3). This view of SOA governance is shown in Figure 9 Dimensions of governance adapted from (Oracle 2007) below.

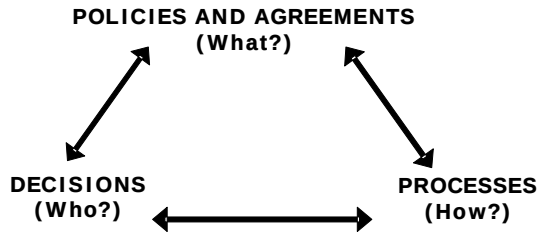

Figure 9 Dimensions of governance adapted from (Oracle 2007)

Despite the numerous definitions of SOA governance and that the methodologies and approaches to SOA governance are often tied to specific SOA governance software

solutions, it is broad agreement that governance addresses two different but related aspects of the service lifecycle - design-time and run-time (Josuttis 2007, Strnadl 2007, Schepers, Iacob et al. 2008, Bertolino, De Angelis et al. 2011). Design-time governance relates to the environment in which services are designed, developed, tested and approved for publication. Aspects of design-time governance include identification analysis and modeling of candidate services, and management of services through the development stage of their lifecycle. Run-time governance addresses the operational aspects of SOA, including the service monitoring, security and management. Registries play a vital role in SOA governance, enabling services to be published, discovered and reused during development as well as the publication, access, control and discovery of production services.

3.5.4 Project governance

A project is "a temporary endeavour undertaken to create a unique product, service or result" (PMI Standards Committee 1996). Projects are distinct from the ongoing repetitive work of organisations.

With increasing joined-up enterprises and whole-of-government approaches, projects transcend organisational boundaries. As with much work undertaken within and jointly by enterprises, SDI capabilities are typically delivered through projects. The important role of projects in building SDI, the unique governance requirements of projects and their relationship to the enterprise and cross organization governance arrangements within which they occur, are all relevant in the context of SDI.

Today in organisations, change is typically achieved through projects. The discipline of project management offers structured methodologies for managing projects to deliver outcomes according to an agreed budget timeline and quality so that planned benefits can be attained. A key feature common to most project management methodologies is that a temporary organisational structure is created to govern and manage the project. These temporary structures may cross organisational boundaries and may not reflect the operational line management structures of participating organisations. This can cause conflict with regard to accountability and reporting in line agencies. In addition, the

products or services that are outcomes of the project need to be transitioned to an operational environment. Both of these aspects are pertinent in the context of SDI

Project governance is a framework within which decisions about the project are made (Garland 2009). In general, project governance provides a framework within which project execution occurs and includes: defining roles and accountabilities, policies and standards for the project, approving the business case and defining the business outcomes, ensuring agency support, buy-in and resourcing, approving project scope and budget, monitoring progress, oversight of project management and steering the project into the organization.

Although there is much in the literature about the separate concepts of project governance and management, little attention is given to how these two perspectives representing project owner and execution authority interact (Klakegg 2009). PRINCE2 (Office of Government Commerce UK 2005), one of the most widely used project management methodologies has developed a standardised approach to project governance and it's interaction with project management, which is worthy of note. In PRINCE2, project governance is referred to as project direction and is a function provided by a Project Board (Office of Government Commerce UK 2005). The Project Board has members representing the three key project stakeholders – the business, user and suppliers of the product or service being developed through the project. The Board steers the project using well defined decision points with a very clearly and formal separation of management and governance.

3.6 Governance definition

Based on the above discussion of governance in a variety of contexts, the following definition of governance has been developed:

> *Governance is a framework that enables communities to manage their collective affairs through a continuous process of negotiation and decision-making. The framework enables the creation of and operates under mechanisms, processes and rules designed to reconcile the diverse needs and interests of a community, to steer individual and collective initiatives of stakeholders to achieve agreed, collective goals.*

This definition of governance will be used as the basis for an examination of SDI governance in the following chapter.

3.7 Chapter Summary

This chapter has presented some theoretical aspects of governance from different disciplines including those of political science, organisation theory and practice, information technology. The various definitions, theories and models of governance drawn from a variety of contexts, provide a useful lens for reviewing SDI governance literature and practice in the following chapter. Selected theories and models articulated in this chapter provide key elements of the SDI governance model.

4. SDI governance

4.1 Chapter overview

Building on preceding chapters which explored SDI theory and practice and the meanings of governance in a variety of contexts, this chapter discusses the governance of SDI. The chapter starts out with an overview of the reasons for the emergence of the term governance applied to SDI and provides a review of definitions and perspectives on SDI governance. This is followed by a brief discussion on the nature of networked, hierarchical and heterarchical SDI governance realities. The chapter then highlights literature and practice related to governance of specific dimensions of SDI such as standards, geospatial resources and registries and provides an exploration of literature largely from SDI theory related to the organisational aspects of SDI as these comprise aspects of governance.

4.2 SDI organizational arrangements

The importance of organizational arrangements as an enabler and a critical element of SDI has long been recognized (Coleman and McLaughlin 1998, Chan and Williamson 1999). The literature provides ample description of the evolving nature of SDI organizational arrangements (Masser 1999, Masser 2005, Singh 2005, Masser 2006, Masser, Rajabifard et al. 2008, Bejar, Latre et al. 2009, Lance, Georgiadou et al. 2009, Singh 2009) and the term governance is often applied to SDI in relation to these arrangements. Further, there has been a recognition of the need to develop appropriate governance arrangements to address SDI implementation challenges both within academia (Kok and van Loenen 2005, Masser 2005, Masser, Rajabifard et al. 2008, Masser 2011, Vaez and Rajabifard 2012) and in practice (Federal Geographic Data Committee 2005, Atkinson and Box 2007, Finney 2007, Kelly 2007). As noted by Box and Rajabifard (2009), recent interest in governance of SDI and attempts to develop appropriate governance responses, reflect an evolving understanding of the role of SDI and its social-political context and that a country's system of governance impacts the nature of National SDI.

However, governance is interpreted in different ways and it is unclear exactly what the term means in relation to SDI. In many instances, it appears to have become short-hand for the collective mechanisms and institutional arrangements that enable an SDI, and in this context has significant overlaps with notions of coordination and leadership.

Given the polysemous nature of the term governance and the evolving nature of the SDI concept, the scope of governance functions and the aspects of the SDI governed, are not clear. From the preceding chapter we can conclude that in broad terms governance is seen as a framework that enables a community to collaborate. The following sections will explore the evolution of the concept of 'SDI governance' and related concepts.

4.3 The evolution of SDI governance

The recent emergence of the concept of SDI governance reflects the evolving nature of SDI, which is in turn driven by significant changes in both in socio-political and technological contexts in which SDI exists. Some of the key changes in SDI that have led to the term governance to gain prominence in relation to SDI are now explored.

4.3.1 From production to process models

The shifting focus of SDI from the concerns of data providers to those of data users, characterised as the shift from product to process models, has been accompanied by a shift from centralised organisational structures to decentralised and distributed networks (Masser 2005). In many instances SDI was initially driven by and focused on the business needs of government mapping and surveying activities. Concomitant coordination arrangements and organisational structures reflected this reality. As these initiatives have evolved and re-oriented over the last decade, the organisational arrangements that existed, were no longer necessarily the most appropriate mechanisms for enabling SDI (Masser, Rajabifard et al. 2008). This is evidenced by the ongoing efforts to find improved SDI governance models in, for example, the US and Australia. In the US, the Federal Geographic Data Committee (FGDC) commissioned the Future Directions Study to develop recommendations for governance of the NSDI (Federal Geographic Data Committee 2005). In Australia, at the national level the Australia New Zealand Land Information Council (ANZLIC) has for some time recognised the key role of governance and the need to improve institutional arrangements as a critical

aspect of developing the ASDI (Committee 2003). With the recent establishment of the Office of Spatial Policy (OSP) and the planned integration of ANZLIC secretariat function into OSP, the governance role of ANZLIC has been redefined (ANZLIC 2012). At the state level in Victoria, the Spatial Information Strategies 2004-2007 and 2008-2010 (Victorian Spatial Council 2005, Victorian Spatial Council 2008) have highlighted the criticality of strong coordination arrangements as an enabler of SDI.

4.3.2 Multi-level SDI implementation

Masser (2005) notes that as applied to SDI, governance, reflects the need for inclusive decision-making in the context of concurrent implementation of SDIs at multiple levels of the SDI hierarchy. In order to address the multi level nature of SDI implementation, Masser proposes the use of hierarchical governance structures (2008).

It has been argued that the SDI hierarchy model does not adequately capture the complexity of interactions between and within SDI levels (Budhathoki and Nedovic-Budic 2006). This viewpoint is reinforced by the theories of multi-level governance (discussed in section 3.3.2.2) together with networked and heterarchical governance realities which holds that although embedded within hierarchies government organisations act increasingly independently from them to address challenges at their level of the hierarchy. Thus agencies in one jurisdiction will increasingly interact, network and cooperate with agencies in neighbouring jurisdictions. In Australia, cooperation between federal and state agencies to respond to environmental and water resource challenges posed by the reduced water flow in the Murray Darling Basin is an example of this type of activity. In fact, it is argued by Paudyal, McDougall et al. (2011) that approaches to SDI development should be re-examined to accommodate the needs of catchment management communities which have non-hierarchical governance arrangements.

4.3.3 Decreasing role of central government

SDI development activities have been increasingly de-centralised from specific agencies at central level to local levels (Masser, Rajabifard et al. 2008). This trend mirrors that reported in the public administration literature that notes decentralisation of central government functions through devolution and de-concentration to lower levels (Kjær 2004, Marks and Hooghe 2004) as part of emerging multi-level governance realities.

4.3.4 Inclusion of the private sector

The trend towards a more inclusive approach to government service design and delivery that includes the private sector and other actors has been documented in the political sciences since the 1980s. Privatization, de-centralization and contracting out of public service delivery occurred as a direct result of limitations of the hierarchical, rigid structures of government to deliver services that require responsive, client-oriented approaches (Lipsky 1980, Osborne and Gaebler 1993, Rhodes 1996).

In SDI literature the role of the private sector in developing SDI is clearly recognised (Rajabifard, Binns et al. 2006, Masser, Rajabifard et al. 2008, Harvey, Iwaniak et al. 2012). Masser (2005) points to the increasing role of the private sector in Canada and Australia due to the development of governance models aimed at more inclusive, 'whole-of-industry' approaches to SDI. In the Australian state of Victoria, for example, an emphasis on a whole of industry' approach led to the creation of the Victoria Spatial Council as the peak governance body, with membership of the private sector, professional bodies and academia (Department of Sustainability and Environment 2006).

4.4 Governance models from political science applied to SDI

Hierarchical governance models (e.g. federal, state, local) remain the basis for political representation needed to approve policies that guide the design and delivery of government services. The hierarchical model is and is likely to remain the prevailing model for government departments and agencies responsible for different elements of government service design and delivery within their respective jurisdictions.

As noted above, the decreasing role of central governments, the dispersal of functions across hierarchical levels, the need to collaborate across jurisdictions and the increased role of non-state actors, have all lead to the evolution of 'network' governance models. The adoption of 'co-production' approaches to service design and delivery is also an important dimension of networked governance approaches (Bovaird 2005).

In the SDI literature, network governance models have been recognised. Based on Australian experience developing a marine SDI, Finney (2007) proposed a generalised governance framework applicable to bottom-up community-driven SDI initiatives. The framework is premised on development of an SDI using an SOA approach, from the bottom-up using open development methodologies, and based around open source community governance models.

Despite the increasing prominence and importance of network governance models such as policy networks, it is recognized that they co-exist and are inter-related with hierarchical governance models (Kjær 2004). The increased role of policy networks does not represent a reduced role for the governing actors, but instead presents new challenges - 'meta-governance' i.e. steering networks (Rhodes 1996, Kjær 2003).

The co-existence of, and relationship between, hierarchical and networked governance arrangements has been noted in SDI literature. Kok and van Loenen (2005), have identified networked organisational arrangements as a critical success factor for mature SDI initiatives, and Masser et al. (2008) have proposed the adoption of hierarchical governance models to address the governance needs of multi-level SDI implementation.

However, as with governance in political sciences there is a view that shadows of hierarchical systems (Héritier and Lehmkuhl 2008) may facilitate the 'joining up' of government geospatial information systems in terms of improving coordination across governance agencies (Lance, Georgiadou et al. 2009). Based on a study of US and Canadian NSDI efforts, Lance, Georgiadou, and Bregt (2009) found that the central budget agency in each country, acting as an external authority body and operating through hierarchical means, has been effective in steering a network of SDI stakeholders and thus enhancing cross-agency coordination.

In reality, governance structures for SDI comprise elements of both hierarchical and network models. As SDI is still typically led by government, which still holds the majority of spatial information resources and remains the key SDI driver, the prevailing hierarchical organisational arrangements of political and bureaucratic elements of government are likely to be a significant factor influencing the design of SDI governance models. This is particularly true when one considers the well-defined,

territorial extents of jurisdictions, and the associated extent of spatial information interests and responsibilities of government agencies embedded within these jurisdictions. Thus, form the foregoing it can be concluded that SDI governance arrangements are heterarchical.

Given that SDI drivers are the real world problems that require sharing of information, and that these problems, such as climate change or water rights management, cross jurisdictional boundaries, the MLG responses observed in the EU and self-organising networks observed elsewhere are likely to be increasingly relevant mechanisms to support governance within and between SDIs. The challenge for higher-level hierarchical SDI governance mechanisms will be to tap into, leverage, enable and empower these self-organising community networks through strategic alignment and delegation of responsibility for decision making.

4.5 Governance and related functions

4.5.1 Leadership and trust

Leadership is a critical factor in SDI success. Kok & van Loenen (2005) for example, use leadership as one of the organisational criteria to assess SDI maturity. However, leadership in SDI is complex. Bellafiore, Bacastow, & Arctur (2008) postulate that while SDI leadership is critical to SDI success, it is the antithesis of good management practice. Leadership is a key aspect of effective governance together vision and the commitment of stakeholders (Masser 2005). Trust is related to leadership and is necessary to secure commitments of participants in collection action. The establishment and maintenance of organizational trust in governance processes and trust in the lead agency are key aspect of effective governance (Harvey 2003).

4.5.2 The distinction between coordination and governance

Approaches to SDI governance have largely evolved out of geospatial coordination efforts. In practice, the terms governance and coordination are used interchangeably and it is worth making a clear distinction between them. The role of governance is to provide a framework for collective decision-making to steer a collaborative initiative. Leadership, whether through a formal or consensual mandate, is a critical dimension of

governance as it provides an additional steering mechanism and overall ownership for a collective effort. Coordination is concerned with the "the organization of the different elements of a complex body or activity so as to enable them to work together effectively" (Oxford University Press 2012). Coordination is thus concerned with processes, activities and actions necessary to ensure the alignment of individual component parts to create a functioning whole. Coordination provides the critical link between the 'steering' processes of governance and the 'rowing' activities of individual actors that move the community in the required direction. In the context of SDI comprising distributed, capabilities that are under different ownership, the role of coordination is critical. However, coordination of SDI is considered to be a distinct and very necessary supporting function for governance.

4.6 Standards governance

As can be seen from the foregoing, SDI governance is considered to be heterarchical, with different aspects of SDI under disparate, and in many cases overlapping governance arrangements. This is perhaps best demonstrated in the realm of standards, as SDI implementation is based on numerous technology and content standards. For example, actors involved in the creation and delivery of a particular geospatial information resource within an SDI, may be governed by a range of organisational, jurisdictional and domain specific standards arrangements related to information content, structure, semantics, and delivery format, all of which have separate governance arrangements.

The proliferation and frequent changes to the core SDI technology standards developed by OGC led to compatibility issues and prompted the proposal for an SDI 1.0 standards suite together with a governance framework developed by Nebert et al, (2007).

Current SDI standardization efforts typically demonstrate a top-down and 'one size fits all' approach (Georgiadou, Puri et al. 2005). As SDI are increasingly built using distributed service-oriented architectural approaches, and there are demands for increasing levels of interoperability at the semantic level within and between SDIs, there is a need to address cross domain harmonisation and thus governance issues.

As noted by Georgiadou et al. (2005) the standardization process needs to be reflexive, with constant monitoring of needs and context to ensure that standards are revised or developed to meet community needs. It is recognised that standards development requires negotiation and the development of appropriate mechanisms and incentives for stakeholders to engage in standards development and implementation. Based on experience in implementing an open standards SDI for the marine community in Australia, Finney (2007) recognises the crucial role of standards governance to provide a mechanism for collaboration within a community to develop standards that enables the realisation of interoperability targets as wells as a mechanism to enable collaboration outside the community to develop, adopt, and through standards profiling, adapt externally governed standards.

4.7 The role of registries in SDI governance

Registries are mechanisms by which artefacts related to agreements (e.g. a service specification) and their implementation (e.g. a service instance) can be published, found and re-used. As such, Atkinson & Box (2007) note that registries provide a mechanism that enables the publication and discovery of artefacts that facilitate the community to implement agreements.

Registries are playing an increasingly important role as critical SDI components that support governance and technically enable SDIs. To date, the majority of registry implementations within SDI implementations can be characterized as containing:

- Metadata about resources that can be downloaded; and
- Links to locations where those resources can be accessed (Tandy and Thomas 2006).

ISO standard 19135 "Procedures for registration of Geographic Items" (ISO 2004) provides a model for registry governance. The model defines actors and roles involved in the operation of registers (essentially lists of resources), and registries that maintains and manage them. This model, shown in Figure 10, details the relationships between the various organizations with a role in the operation of registries and registers.

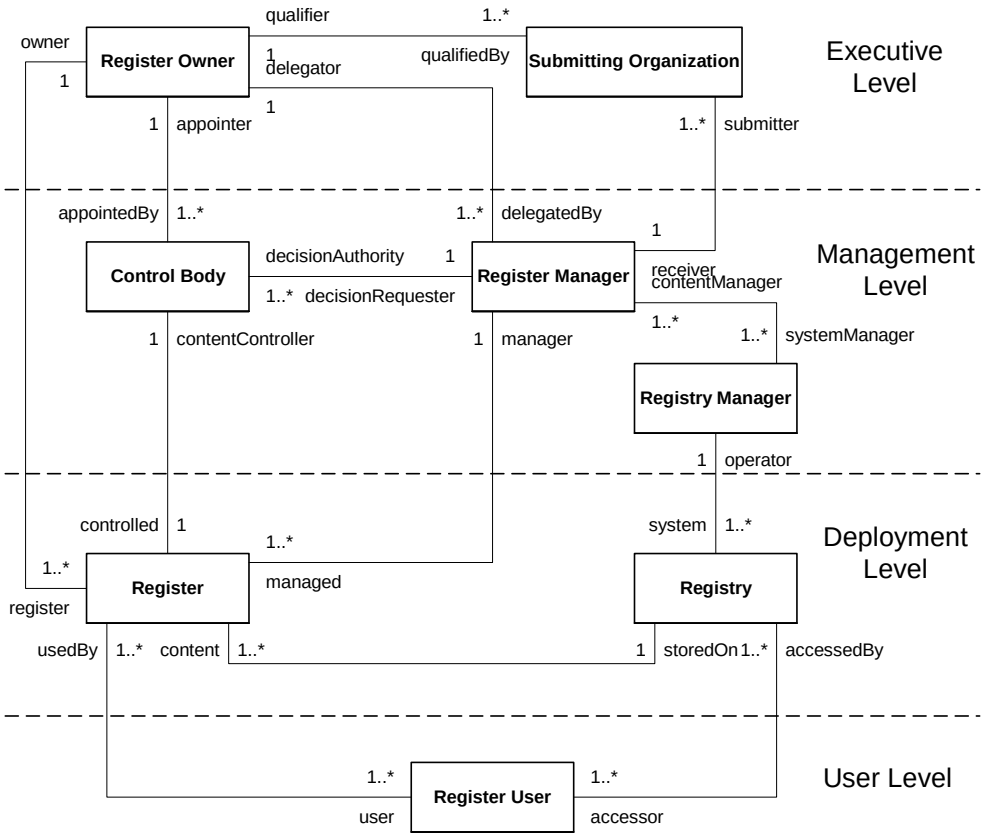

Figure 10 Roles related to the operation and use of registers (ISO 19135) (ISO 2004)

In essence, the ISO 19135 model essentially describes a process, key roles and information requirements to effectively govern geospatial resources using a registry.

Some of the key aspects of the roles and responsibilities related to this registration process are as follows:

Register owner

- Responsible for the management/dissemination and intellectual content of a register;
- Specifies criteria to determine organizations that can act as submitting organizations; and
- May serve as the control body or may delegate role to sub-group within the organization.

Register manager

- Role delegated by register owner;

- May delegate operation of the registry (on which the register resides) to a registry manager;
- Accepts and manages proposals from submitting organizations; and
- Passes proposals to the control body for decisions.

Submitting organization

- Register manager determines eligibility of organization to submit register change requests.

Control body

- Group of technical experts appointed by a register owner to decide on the acceptability of proposals for changes to the content of a register; and
- Makes decision on proposals provided by the register manager.

Registry manager

- Responsible for the day-to-day management of a registry; and
- Provides means for electronic access to the registry for register managers, control bodies, and register users.

4.8 SDI governance perspectives from US practice

Although governance has not been well addressed in the SDI academic literature to date, experience in SDI governance in practice at national and state levels in the United States of America is useful for supplementing and comparing with findings from research into the Australian context, detailed in the case studies section of this thesis. The following sections provide a brief overview of national and state level perspectives on SDI governance in the US.

4.8.1 US NSDI governance arrangements

Given the large number of stakeholders in the US, governance presents a significant challenge. The Federal Geographic Data Committee (FGDC) an interagency committee that promotes the coordination of geospatial data at a national level is the peak

geospatial data coordination body and is responsible for the US NSDI. The structure of the FGDC comprises four components. These are:

- Policy level Steering Committee that provides leadership and direction for member agencies which produce, maintain or use spatial data directly;
- Coordination Group that advises on the day-to day business of the FGDC;
- Agency-led subcommittees organized by data themes and cross-cutting Working Groups; and
- Secretariat that administers FGDC activities hosted by the U.S. Geological Survey (USGS).

In 2004 the FGDC and the USGS National Geospatial Programs Office (NGPO), commissioned a team to develop recommendations for NSDI governance. The report produced by the team, based on analysis of existing geospatial program governance structures and extensive interviews with geospatial community leaders, provided the following definition of SDI governance:

"The organizational structure, leadership and authority roles, and all associated regulations, policies, and procedures for management, coordination, and operation of the NSDI" (Federal Geographic Data Committee 2005 p. 3).

The report identified the following as critical elements of governance:

- Underlying legal mandate(s);
- Clear responsibilities and roles;
- Leadership/authority;
- Accountability;
- Budget; and
- Stability.

4.8.2 US state - governance models

To support the development of state-wide geospatial governance arrangements for Wisconsin State, a review of geospatial coordination arrangement was carried out in 2007 for the 8 US States (Wisconsin Department of Administration 2007). Based on the findings of this review, two potential governance models were suggested - a 'congress'

model and a 'hierarchical council' model. To assist stakeholders in evaluating the two models, required characteristics of governance related to fundamental governance principles were identified. These principles and characteristics of good SDI governance are presented in Table 1, below.

Table 1 Criteria for evaluating geospatial governance models (Wisconsin Department of Administration 2007)[2]

Principle	Aspect	Key Characteristics
Legitimacy & Voice	**Participation**	- Broad and balanced representation - Communication between Council and stakeholders
	Consensus Orientation	- Mediation of differing interests to reach a broad consensus
Direction	**Strategic Vision**	- Enabling mechanism and a clear mandate - Clearly defines roles and responsibilities - Joint and clearly articulated vision and mission
Performance	**Responsiveness**	- Access expertise and resources from within and outside Council to address and resolve issues.
	Political Efficacy	- Enables the geospatial community to articulate a united vision to policy makers - Increases awareness of geospatial issues among policy makers - Involves highest level policy makers in decision making - Promotes incorporation of geospatial issues into policy
	Effectiveness	- Best practices from the private sector

[2] Adapted from Graham, J. *et al.*, 2005. Principles for Good Governance in the 21st Century (August 2005). Institute on Governance, Canada. IOG Website: http://www.iog.ca, accessed December 10, 2007.

	and Efficiency	- Capacity building at all levels - Influence expenditure decisions - Provide incentives for participation
Accountability	**Accountability**	- Clearly defined reporting requirements
	Transparency	- Transparent mechanisms for participation in decision-making
Fairness	**Equity**	- Active stakeholders participation - Stakeholders receive sufficient value from the Council
	Rule of Procedure	- Clearly defined, open and fair operating and voting procedures
Sustainability	**Sustainability**	- Ability to persist under change in administration - Ability to persist under budgetary constraints - Sufficient funding, administrative support and technical support

4.9 SDI governance definition

The following definition of SDI governance based largely on the FGDC definition is proposed:

> "An overarching and enabling decision-making and accountability framework comprising authority structures, roles, policies, processes, and mechanisms that enable collective decision-making, and collaborative action to achieve common goals" (Box and Rajabifard 2009)

4.10 Chapter summary

Building on previous chapters that explored the evolving concepts, theories and models of governance and SDI as conceptually and theoretically distinct, this chapter has reviewed body of work on SDI governance itself. This has entailed drawing together disparate references to SDI governance, and organizational arrangements and

coordination in academic literature to review the current theoretical understanding of SDI governance. The chapter also provided a brief description of standards governance and presented an overview of selected material from SDI implementation practice in the US, concluding with a definition of SDI governance.

5. SDI governance case studies

5.1 Chapter overview

Given the limited academic literature on SDI governance and lack of clarity around definitions of and approaches to governance, this research aims to contribute to the body of knowledge through exploring SDI governance in the Australian context. This chapter presents the case study based research methodology describing case and participant rationale and methodology. The chapter then provides an overview of each case study, with a description of pertinent aspects of its institutional architecture, based on document review and information collected though interviews. Subsequent sections present and discuss the analysis of the outcomes of the interviews and focus groups together with key findings.

5.2 Research methodology: The case study approach

As SDI and governance are contested, complex, evolving, subjective, and multi-faceted concepts with interwoven social and technical dimensions, there is tremendous variability in how SDIs are conceptualized in theory and realised in practice. Although there is limited literature relating to theoretical or practical aspects of SDI governance, there are implicit and explicit expressions of governance in implemented SDI. Information about how governance is conceptualized and implemented in practice exists in a variety of forms, with the principle sources being individual knowledge and perceptions, and documentation related to particular initiatives.

Due to the variable, complex and intrinsically social nature of the phenomena under investigation and the sources and nature of information about SDI governance, an exploratory case study approach was chosen for this study. Yin defines a case study as an "empirical inquiry that investigates contemporary phenomenon within its real life context, especially when the boundaries between the phenomenon and context are not clearly evident" (1994 P. 13). As the case study approach aims to answer 'how' and 'why' questions and copes with distinctive situations with multiple variables, it is well suited for exploring SDI governance.

5.2.1 Case study selection

To address variability between SDIs, this research used multiple case studies selected through purposive sampling. The use of multiple cases was considered better suited to supporting development of a model through 'analytical generalization' as opposed to 'statistical generalization' (Yin 1994), i.e. the ability to make inferences about all SDIs.

Although statistical generalization was not a goal of the research, an attempt was made to identify paradigmatic cases studies representative of different types of SDIs in order to obtain a broader perspective on SDI governance. An SDI typology, adapted from the SDI process model (Rajabifard and Williamson 2001), was used to identify cases studies. The characteristics of SDI's according to this typology are presented in the first and second columns of Table 2, below. Case studies, described below, were selected to represent different hierarchical levels, scope, and organizational arrangements. Reflecting Australia's federal model (comprising a national government, five state and two territory governments), the research focused on the following four initiatives at state/territory and national levels:

- **New South Wales State Natural Resource and Environment Sector SDI** - The case study focused on the Community Atlas for Natural Resources (CANRI), an interagency programme to develop an SDI to improve management of and access to natural resource information. The evolution of CANRI from program governance to operational governance, and later transition to the Natural Resource Atlas (NRAtlas), were key aspects analysed in this case study;
- **Victoria State SDI (VSDI)** – this case study focused on the evolving institutional arrangements for development of the Victoria SDI;
- **Western Australia State SDI (WALIS) -** The Western Australia Land Information System (WALIS) – the state-wide geospatial coordination arrangements and a multi-agency program to develop the Shared Land Information Platform (SLIP), the service oriented infrastructure to support land administration, environment and emergency services business focus areas; and
- **Public Sector Mapping Agency (PSMA)** - a public company established and owned by Australian Federal, State and Territory governments to integrate and

deliver key State and Territory datasets for which consistent national coverage is required.

Table 2 below shows the case studies according to the characteristics of the typology. This mapping indicates that the four case studies are representative of and reflect a combination of the typology characteristics.

Table 2 Case studies mapped to SDI typology

Dimension		**Characteristics**	**Case Study**			
			CANRI	**VSDI**	**PSMA**	**WALIS/ SLIP**
Level		National			X	
		State	X	X		X
		local				
Purpose:		Clearly defined business purpose	X		X	X
		Framework for data access/exchange		X		X
Scope	People	Operated by single agency			X	X
		Operated by multiple agencies	X	X		
	Access network	Access to metadata describing data	X	X	X	X
		Access to data via services	X	X	X	X
	Agreements	Organisational level – e.g. policies	X	X	X	X
		Technical level – e.g. specifications standards for technical elements	X	X	X	X
	Data	Single business area focus	X			
		Multi-domain		X	X	X

Figure 10 below, indicates the relative position of the selected case studies in the SDI hierarchy within Australia. A narrative description of each case study, together with an analysis and synthesis of the cases, is provided in section 5.5 below.

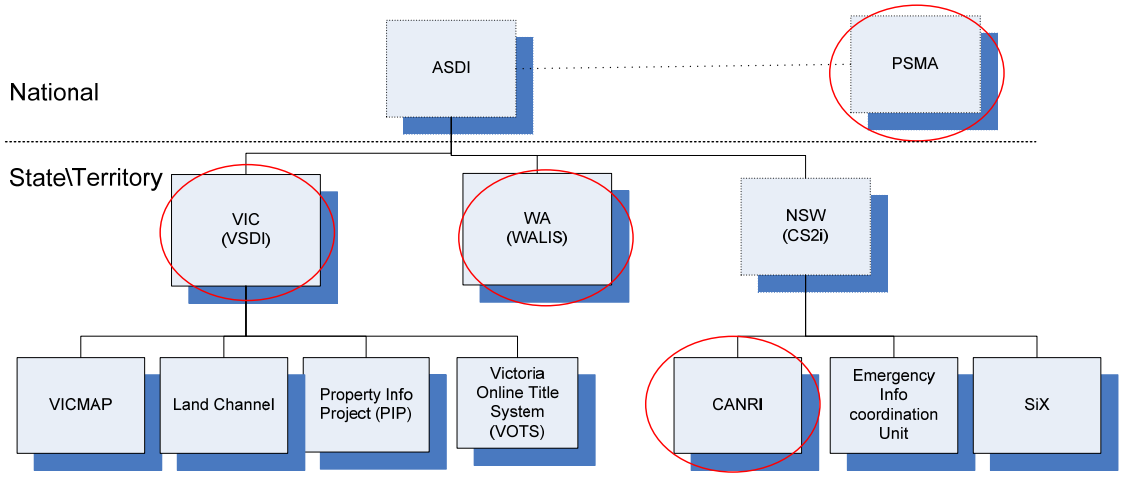

Figure 10 Position of case studies in the Australian SDI hierarchy

5.3 Research methods

The following sections describe the interview and focus group research methods used to collect data from the case studies.[3]

5.3.1 Interviews

5.3.1.1 Method

Key informant interviews were conducted to obtain information about the realities and issues associated with governance in each case study. The use of key informants permits the capture of an informed insider perspective (Kayrooz and Trevitt 2005).

In line with the exploratory nature of the research and the varied nature of SDI and their attendant governance challenges, a semi-structured interview approach was used. This type of interview, structured around a set of predefined topics of interest, enables

[3] Interviews and focus groups were conducted between August and October 2008.

interviewees to provide detail in areas that are relevant to their experience. This approach also enabled the flexibility and freedom to explore a range of topics of interest to the interviewee, or of relevance to the research.

Background research to develop an understanding of the nature and current understanding of SDI and governance concepts from both literature and practice, was used to inform the organisation of the semi-structured interviews around specific topics. Topics used to structure the interviews were as follows:

- Defining SDI - to capture the interviewee's understanding and perspectives on SDI to guide further questioning;
- Defining and dimensioning SDI governance – defining governance, determining the scope of governance in the context of the case study and describing governance processes and mechanisms for the SDI;
- Identification of key governance challenges, solutions and lessons learned.

These topics represent what is considered to be a logical separation of concerns that were addressed in the sequence presented above. This ensures that the discussions followed a logical order with each topic under discussion providing context for the next topic. The rationale for selection of each of the topics is as follows:

- Defining SDI - given the multi-faceted and evolving nature of SDI and its conceptualisation, identified through background research, confirming a shared understanding of what is meant by SDI was considered to be a critical starting point for discussions;
- Defining and dimensioning SDI governance – this topic covered a range of issues starting with a definition of governance to explore discussants understanding of governance, which from the research is a contested and often misinterpreted concept. Discussion in this topic area then focused on trying to determine the scope of SDI governance and key governance mechanisms. Defining the scope of governance was an issues identified in research as being problematic given the often intersecting, overlapping heterarchical governance regimes that exist in practice; and

- Identifying key challenges and potential solutions – this topic was included for pragmatic reasons to enable extraction form the discussion of some lessons to guide practice and inform model development

5.3.1.2 Participants

Nine individuals were identified as potential key informants based on their governance role within the respective SDI initiatives. An attempt was made to select key informants engaged in governance related tasks typically working within organizations exercising key governance functions. Six individuals were contacted and all agreed to participate in interviews.

To supplement the views of key informants, two additional interviews were conducted with informants from the private sector, individuals working for an SDI services and solution provider and a web service catalogue solution provider. In addition, a representative of OGC Australasia was interviewed.

In total nine semi-structured key informant interviews were conducted. A description of the key informants and their agency's role with regard to governance of the SDI along with the scope of the interviews is presented in Table 3, below.

Table 3 Key informants organisation and interview scope

Interviewee	**Organisation**	**Interview scope**
Staff member	DSE, VIC	VSDI
SDI services consultant	Withheld for reasons of anonymity	CANRI
Representative	OpenGeospatial Consortium	SDI in general
Staff member (2 people)	PSMA	PSMA
Staff member	Office of Spatial Data Management (GA)	VSDI, PSMA
Commercial spatial web services solution provider	Withheld for reasons of anonymity	SDI in general
Former staff member	Landgate	WALIS

5.3.2 Focus groups

5.3.2.1 Methods

To explore and analyse the range of views about SDI governance that are likely to exist in a diverse community, particularly given the typically subjective interpretation of the term governance, focus group discussions were conducted. A focus group discussion, defined as a number of people that have shared experience discussing ideas and perception related to a research topic (Kayrooz and Trevitt 2005) was considered to be a particularly useful approach for this research because of both the collective nature of governance and the interaction between group members that focus groups facilitate. On a pragmatic level, focus groups also provide a means of capturing a large number of perspectives that would not otherwise have been possible given research resource constraints.

In line with the individual interview approach, focus group discussion guides were framed around specific pre-defined topics as follows:

- SDI – definition, and components, implementation realities;
- SDI governance – definition, scope and mechanisms; and
- Governance challenges and solutions.

Participants were given an opportunity at the outset to identify additional issues for discussion and the format was kept as flexible as possible to accommodate participant-led discussions. Methodologically, the sessions comprised brain-storming for the whole group plus break-out group discussions with reporting, synthesis and analysis in plenary.

5.3.2.2 Participants

Two focus group sessions were organised to explore perspectives on governance in the context of the Victorian and NSW SDI initiatives. Although end-users are recognised as key stakeholders and need to be involved in decision-making (specifically in regard to the purpose of the SDI and information and functional requirements) the research focused on those stakeholders actively involved in providing SDI capabilities. Therefore, focus group participants were drawn from stakeholders with responsibility

for, or doing the work of, designing, managing, operating, supervising, and coordinating SDI capabilities.

Focus group sessions were arranged for the VSDI case study in Melbourne (with 7 participants) and for the CANRI case study in Sydney (with 5 participants). Key informants in each case study assisted in identifying other participants for focus group.

5.3.3 Data analysis methods

The data analysis methodology comprised the following processes:

- Notes from individual interviews and focus group discussions were transcribed and sent to interviewees and focus group participants for verification;
- The notes were consolidated and triangulated against available documentary evidence including reports, and academic publications related to each case;
- Notes were summaries into main points; and
- Main points were synthesised, reviewed and organised into themes that emerged from the material with an indication of issues appearing across more than one case study.

5.4 Case Studies

5.4.1 Victorian Spatial Data Infrastructure (VSDI)

This case focused on the emerging and evolving governance arrangements for the Victorian SDI, a State-wide SDI. Efforts to build the VSDI commenced in 1993 guided by a series of Victorian Spatial Information Strategies (VSIS) (Victorian Spatial Council 2005) which identified core spatial information needed by government. With the creation of Land Victoria within the Department of Sustainability and Environment (DSE) (Masser 2005) it became the main coordination body for spatial information in the state.

The spatial information management framework plays a central role in Victorian SDI (VSDI). The framework is based on four elements (VSC 2010):

- Institutional arrangements for developing spatial information;
- Requirements for creating and maintaining spatial information;

- Mechanisms for making spatial information accessible and available; and
- Strategic development of technology and applications.

In 2004, the Land Information Group of Land Victoria became the Spatial Information Infrastructure (SII) and in 2006, the Victorian Spatial Council (VSC) was created as the peak spatial information governance body, together with the Victorian Government Spatial Committee (VGSC) which was established to coordinate a whole of government approach to spatial information. The VSC comprises an independent chair and 12 members, representing state, local and federal government, academia, geospatial professions and the private sector. The VGSC which was established in conjunction with the VSC has 12 members representing State government departments and is chaired by the Chief Information Officer (CIO) of the Department of Premier and Cabinet (DPC). The VGSC reports to the ICT Policy Committee (Department of Sustainability and Environment 2006).

The SII plays a pivotal role in the governance of the VSDI. SII also acts as secretariat for the VSC. In practical terms this involves provision of logistical and administrative support to the VSC, as well as input into the development of strategy and policy. The VSC makes a distinction between coordination mechanisms and governance functions stating that "the VSIS defines the coordinating mechanisms that will achieve its objective to facilitate effective use of spatial information, governance will be the means of giving effect to them." (Victorian Spatial Council 2006 p. 8). In this context VSC conceives governance as being the "the way in which decisions are made and implemented" (Victorian Spatial Council 2006 p. 8).

5.4.2 Community Atlas Natural Resources Initiative (CANRI)

This case study focuses on the approach to developing an SDI through a multi-agency program with dedicated funding and a clearly identified business case. This focus enables the investigation of issues associated with governance of SDI in program implementation mode and its transition to an operational context.

CANRI was an interagency programme funded over four years from 2000 to 2004 with a $4 million budget. Its aim was to improve the management of and access to distributed natural resource information held by a range of government organisations.

In 1996, the heads of the NSW Government natural resource and environmental agencies agreed to adopt a whole-of-government approach to the management of natural resources information in NSW through the development of a State-wide Natural Resources Information Management Strategy (NRIMS). A Steering Group representing 13 NSW Government agencies involved in natural resource management was established to develop and implement the strategy. The Community Atlas for Natural Resource Information (CANRI[4]) program was one of the key initiatives of the NRMIS. It was conceived as a whole-of-government program to deliver seamless access to natural resources information involving the 13 NRIMS agencies.

Through a programme of related projects, CANRI addressed six themes: coordination, data, systems, quality and standards, products and services, and communications. Custodial arrangements for CANRI information products were based on the custodianship guidelines developed by ANZLIC.

The CANRI program was overseen by the NSW NRIMS Steering Group made up of information managers from the NSW State natural resource and environment agencies. The NRIMS Steering Group established the CANRI Program Board comprising comprised NRMIS Steering Group representatives, the CANRI Program Director and Chair of the Community Reference Group (CRG). The Board was responsible for implementing the program and reported to the NRMIS Steering Committee.

[4] CANRI is now known as the NSW Natural Resource Atlas

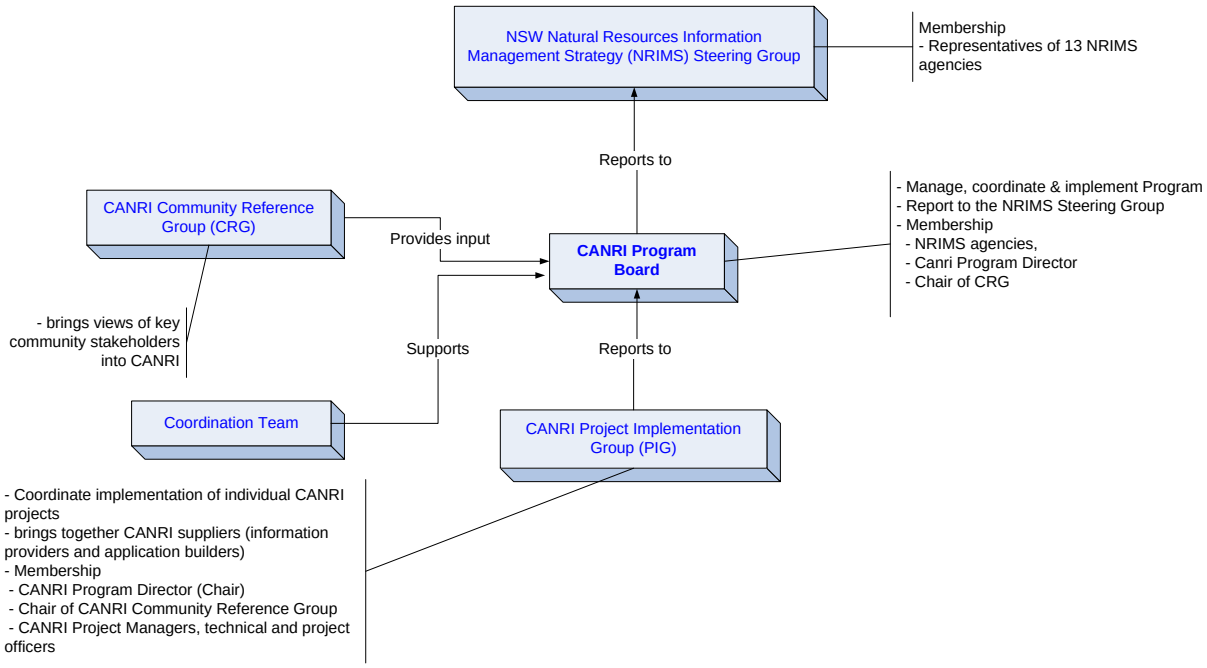

Figure 11 CANRI program governance arrangements

The Board was supported by a Coordination Team located in NSW Department of Infrastructure, Planning and Natural Resources (DIPNR). A Project Implementation Group (PIG) reporting to the Board was created to bring together CANRI suppliers (information providers and application builders) to ensure that the program was implemented efficiently and in an integrated manner. Other stakeholders were involved in governance of CANRI through the Community Reference Group (CRG) which was formed to ensure inclusion of community stakeholder views.

During and after the life of CANRI, NSW natural resource management agencies underwent major organisational changes with natural resource management functions being passed from DIPNR to a newly created Department of Natural Resources (DNR), and in 2007, these functions were rolled into two agencies, the Department of Water and Energy (DWE) and the Department of Environment and Conservation, which was renamed the Department of Environment and Climate Change (DECC). The Department was renamed in April 2007 as part of the merger of the former Department of Natural Resources and NSW Greenhouse Office with the Department of Environment and Conservation. In 2011, the Department was broken up with its responsibilities split between the new Office of Environment and Heritage (part of the

Department of Premier and Cabinet) the Department of Trade and Investment, Regional Infrastructure and Services.

5.4.3 Public Sector Mapping Agency

This case focuses on the rather unique situation of a private company created and wholly owned by the Australian Governments to deliver seamless nationwide spatial information products.

PSMA Australia was formed in 1993 as a joint venture between the nine States, Territories and the Federal Governments of Australia, to deliver mapping services for the 1996 Census. Following the success of the initiative, ANZLIC passed a resolution calling for an expanded PSMA role to provide access to the census data set as well as to establish a mechanism to provide appropriate additional national data (Masser 2005). In 2001, the Governments of Australia established PSMA Australia Limited a company wholly owned by the State, Territory and Australian Governments (Holmes 2009). PSMA Australia combines spatial information from Australia's governments to create seamless national spatial datasets that include features such as roads, street addresses, and cadastral and administrative boundaries. Dataset are used by a network of partners to develop products and services to deliver information to end users. PSMA Information products are sold via PSMA's partner 'value added resellers'

PSMA is governed by a Board of Directors. The State, Territory and Australian Governments each nominate a Director to join the Board. The Chairman is an independent, non-executive Director. The agencies and organisations that collect and control the data which PSMA Australia uses to build national digital mapping datasets are known as 'data custodians'.

5.4.4 Western Australia Land Information System (WALIS)

This case focuses on a collaborative, partnership-based approach taken by government agencies in Western Australia to sharing government spatial information, spanning more than three decades, dating back to 1978 with the report recommending the creation of a land information system for Western Australia (Burke and Piesse 2013)

Western Australia Land Information System (WALIS) was established in 1981 as a partnership of government agencies working with commercial, academic and end user communities to manage and promote the Western Australia's geographic information. WALIS coordinates access and delivery of the geographic information held by WA Government agencies and aims to build networks of people and technology to share land and geographic information. WALIS is in essence an institutional framework that enables collective decision-making and co-ordinates the State's geographic information. WALIS operates through a number of committees that represent the interests of WALIS stakeholders and the WALIS office.

The WALIS Office formulates strategies, produces standards and policies for data management and access. Since 2000 WALIS has been developing the Shared Land Information Platform (SLIP) the technical framework that enables sharing and access to spatial information.

WALIS comprise three tiers of governance, a governing body - the Executive Policy Committee, a strategic body - the Spatial Management Group and a Council, comprising representatives from each of the WALIS member agencies, which focuses on operational coordination and information exchange.

In 2004, Department of Lands proposed to WALIS the adoption of an information sharing framework that the Department had been developing (Western Australia Land Information System (WALIS) 2006). WALIS membership endorsed this proposal and government provided funding to develop the Shared Land Information Platform (SLIP).

SLIP is a shared information delivery platform based on an 'enabling framework' of servers providing access via web services to distributed point of truth data held by custodian data. SLIP delivers information across four themes, Emergency Management (EM), Natural Resource Management (NRM), Interest Enquiry (IE), and Electronic Land Development Process (ELDP) (Western Australia Land Information System (WALIS) 2006). In 2006, responsibility for managing the Shared Land Information Platform (SLIP) was transferred to the WALIS Office which was integrated into the Department of Land Information (DLI). In 2007, the DLI transitioned to a Statutory Authority, the Western Australia Land Information Authority, trading as Landgate.

5.5 Key Findings

5.5.1 Key themes

The main discussion points from the interviews and focus groups were organised around the following four main topics that emerged from the research:

1 **Institutional arrangements** – given the focus of the research on governance, not surprisingly, a significant proportion of interview and focus group discussion related to institutional arrangements for SDI;

2 **Business dimensions**- given the challenges associated with a large scale, multi-stakeholder, and expensive infrastructure development program, there was a great deal of discussion related to how to fund and drive SDI through articulated business cases with specific domain based information communities;

3 **Data** – as the rationale for SDI is the delivery of spatial information, a key theme of discussion related to spatial data, its creation, maintenance, financial sustainability, curation and governance; and

4 **Technology** – The major focus of SDI development effort is on 'the plumbing' i.e. designing and building a shared technical infrastructure to deliver information. Agreements from high level policies to technical specifications which enable common approaches, are a major focus area for governance activities and therefore there was a fair amount of discussion related to technology aspects of SDI

5.5.2 Overview of findings

In broad terms there was strong consensus amongst the interview and focus group participants across case studies, regarding definitions of SDI, and governance challenges. In particular, there was strong alignment of views around the critical collaborative nature of SDI, key challenges in operating in a collaborative environment and the critical role of governance, leadership, mandate, and clearly identified business drivers for SDI.

There was a fair degree of commonality related to SDI success factors across case studies. A universal theme related to the nature of collaboration and engagement which is underpinned by trust. Trust between organisations is developed through collaborative activities and depends upon relationships developed between individuals working in

different agencies. The significant institutional restructuring and reorganisation in State government agencies and the impacts on individuals and their roles, negatively impacts theses relationships.

A significant and fairly consistent topic of conversation related to tension between the need to develop a generic, application-neutral infrastructure through clearly identified and domain-specific, business drivers. In the case of SLIP for example, WALIS provided the institutional framework for governance and coordination that enabled a self identified sub-communities to organise around clear business drivers to make a business case for investment in SDI. In the case of SLIP, the initial driver was the land administration use case and the value delivered by SDI for this one use case, justified the development of a generic infrastructure to support additional use cases. This was echoed by CANRI, as the infrastructure was developed with to a range of initially identified use cases related to natural resources.

A notable exception to the common viewpoint shared by participants, related to attitudes towards data access and pricing arrangements and the funding models for SDI. In PSMA and VSDI cases, there was much discussion around the need to sell spatial data and the use of revenue from this to fund geospatial collection management and delivery mechanisms like SDI. This is in stark contrast to the CANRI and WALIS cases in which this issue was not discussed. It is worth noting that both CANRIS and SLIP infrastructure was built through dedicated funding provided by respective State Governments.

5.5.3 Governance lessons learned

Table 4, below, provides a synthesis of the most commonly cited lessons learned from the case studies. These have been grouped into the four themes described above and ranked in order of the most frequently cited.

Table 4 SDI implementation lessons learned

Institutional dimension
Success of SDI initiatives is based on the trust & goodwill established in a community over years and based on personal relationships.

Barriers between the geospatial and IT communities hamper efforts to build SDI.
SDI governance arrangements and existing government (including Whole of Government) and domain governance arrangements need to be aligned.
Key agencies (and individuals within them) typically have multiple roles in SDI including lead agency, custodial, secretariat of governance body, coordinator, and operator of the infrastructure. These roles must be clearly understood and separated.
Governance operates through representational processes and the effectiveness of the process is dependent on the quality of the representation.
For effective governance, agencies acting as community representative must subordinate the interests of their own organisation to those of constituency being represented.
Current SDI approaches and governance models reflect a hierarchical structured government world view, which does not adequately accommodate network and market-oriented realities of the geospatial industry.
SDI implementation requires leaders in individual agencies to champion the collective initiative.
With institutional changes (organisations, people and roles), business drivers, motivation, priorities and power balance changes. This results in a loss of momentum and a need to re-build partnerships and trust.
Governance mechanism should encourage participation of and give voice to smaller agencies.
Government to government business is hampered by weak contract arrangements and weak enforcement mechanisms with contract performance based on trust.
Business dimensions
There is a need to understand the business drivers for SDI.
There is a need to ensure alignment of business outcomes of individual agencies with collective interests.
There is a need to convincingly answer the question "What's in it for me?" for potential participants in an SDI initiative to engage them and achieve their active participation.
Selling SDI to participants using the benefit of increased efficiency alone is problematic, as this may be perceived as a threat – i.e. it represents loss of budget/staff/status/power.
Justification for obtaining agency funding to participate in SDI is problematic as the benefits are realized by users outside of the organization (which maybe beyond the business goals of the funding organization).

Reticence of agencies to participate in SDI can be overcome by demonstrated positive benefits and results.
Data
Complexity, lack of standards and guidance related to data licencing is cited as a key barrier to the sharing and publication of geospatial data and thus achieving goals of SDI
Liability concerns related to incorrect data or misuse of published data are cited as reason for non-publication of data.
There is a need to adopt a transactional view towards data access, pricing and licencing. The current approach of accessing data sets based around physical data storage reality is out-dated.
There is an accountability gap with regard to data custodianship. Custodial responsibility is typically mapped to an organizational level. However, in reality, geospatial data is typically managed in business units and with corporate IT governance focuses on corporate data.
Geospatial data is critical component of SDI. It's expensive to create and manage this information. Agencies have different policies and practice in relation to data pricing. This heterogeneity acts as a significant barrier to data sharing.
Services and technology
Entrenched business practices are cited as barriers for low uptake of geospatial web services by GIS users. There are however real technical limitation (bandwidth, speed) that are barriers for low uptake of geospatial web services by GIS users. Governance needs to ensure collective agreement around the design of appropriate functionality delivered through agreed services and technologies.
Service quality limitations (e.g. availability) are cited as barriers for low uptake of geospatial web services by GIS users.
To enable SDI stakeholders to participate in the SDI adequate technical support and mutual learning opportunities are required.
SDI participants have heterogeneous technologies, implement services differently and have to date achieved syntactic interoperability only (common data exchange formats and structures) There is a need to address semantic interoperability (common concepts and definitions).

5.5.4 SDI governance recommendations

In addition to the lessons learned, some key recommendations drawn from the case studies are presented. These relate to SDI governance or aspects of SDI that have significant governance dimension that are considered to be generic and thus broadly applicable, are presented below. These are grouped around themes that emerged from recommendations provided by participants.

Leadership, mandate and neutrality - The need for clearly defined leadership, a sustained formal mandate, including a policy framework, and the neutrality and community-oriented action of organizations playing key governance roles are all critical requirements for effective SDI governance. Participants recommended that:

- A high-level policy framework to provide sustained formal mandate and mechanism for collaboration between individual agencies be established;
- A lead agency be identified and provided with a clear mandate to lead, a role that must be exercised with neutrality;
- A rotating chair for governance bodies be established to aid neutrality and enhance participation and buy-in from smaller agencies; and
- An independent chair for peak governance body (ultimately responsible for SDI implementation), be appointed.

From project to operational governance - Sound project governance and a clear transition plan to move from temporary project governance to operational governance in a multi agency context is a major governance challenge. Participants recommended that:

- Since SDI capabilities are typically implemented as a series of inter-dependent projects, a project management approach/framework such as PRINCE2[5] be used to ensure effective coherent project governance;
- Project governance should focus on the meeting the business case, project, design and delivery while operational governance should focus on the ongoing operation and sustainability of the SDI;

[5] Projects in a Controlled Environment - http://www.prince2.com/

- Effective links and interfaces are established between project governance mechanisms and enclosing and related governance frameworks (e.g. geospatial community, political, administrative and regulatory system and corporate governance); and
- A clear transition plan to move from project to operational governance be developed.

Licencing and data sharing - Addressing the concerns of data custodians will assist in removing barriers to publication. Participants recommended that:

- Legal concerns (such as licencing and liability) that act as barriers to geospatial data sharing be addressed through improved licences for spatial data and provision of feature-level licence information as critical metadata.

Business, institutional and technical architecture - Developing separate institutional and technical frameworks that are business neutral will greatly enhance prospects for growing an SDI. Participants recommended that:

- Long-term sustained, institutionally independent, business drivers for the SDI be identified;
- The financial investment in SDI be justified using cost benefit analysis or return on investment in at least one business area. Other business areas where investment is harder to justify can leverage the established infrastructure;
- The institutional and technical frameworks that comprise SDI be separated;
- The technical infrastructure be developed as a 'business-neutral' enabler;
- Self-identified business areas e.g. environment, emergency response, marine be enabled to develop business cases and exploit/grow the infrastructure; and
- A mix of part-planned and part evolving approaches to infrastructure development that encourages innovation and heterogeneity be adopted.

5.6 Chapter summary

This chapter has provided a description of the case study research, presenting the case selection methodology and rationale, data collection methods and participant selection, together with a description of the data analysis methods. The chapter then provided a

description of the case studies and presented case study findings consolidated around key themes which emerged from the research.

The case study research has provided insights into SDI governance realities and responses. This provides valuable optics on selected Australian SDI initiatives and their approaches to addressing SDI governance challenges. This enables the abstraction of some common elements of SDI governance which has been used to inform the development of the SDI governance model presented in the next chapter.

6. The SDI governance model

6.1 Chapter overview

This chapter presents the SDI governance model. The chapter provides a description of the rationale for modeling together with guiding principles and foundational concepts for the model. The chapter then articulates the model for SDI governance. The model is presented using three perspectives; 'the what' - defining the scope of governance focused on technical decision domain (i.e. issues related to geospatial resources and agreements); 'the who' - roles and responsibility in relation to governance; and 'the how' - key process that are used to exercise governance.

6.2 Modeling methodology

6.2.1 Overview

Modeling is undertaken "to capture and state requirements and domain knowledge so that stakeholders may understand and agree on them" to support the design of a large complex system (Rumbaugh, Booch et al. 2004 p. 15)**.** The governance model presented in this chapter provides a high level, abstracted view of reality. The aims of the model are to:

- Unambiguously define concepts and how they relate to each other;
- Develop a common understanding of the phenomena and processes comprising SDI governance; and
- Articulate a replicable, conceptual approach to addressing governance of the technical domain of an SDI.

6.2.2 Model development methodology

The model has been developed through a stochastic approach and draws on:

- Key aspects of governance emerging from SDI governance case study analysis;
- An understanding of the SDI and broader contexts of governance from literature and practice; and
- IT governance practice - in particular ISO 19135 - registration of geographic items and elements of TOGAF.

These inputs were used to develop a model that defines key concepts and dimensions of SDI governance, the scope of governance and its relationship to other SDI enabling functions and processes. In the development of this model, governance is treated as a sub-system of the SDI model. This enables the analysis and specification of governance using formal systems analysis and modeling approaches and tools.

The governance sub-system is presented in next two sections. Section 6.4 describes several key aspects of governance to provide context for the governance model (presented using a combination of Unified Modeling Language (UML) and *ad hoc* graphical notation to explain concepts where appropriate). Section 6.5 presents the registry-based governance model using UML notation.

6.3 Case study contributions to model development

Several important findings from the case study research influenced the development of the model. Firstly, a significant proportion of interview and focus group discussion related to institutional arrangements for SDI. Institutional arrangements have a very tangible aspect i.e. the existence of committees and working groups and other bodies and thus are easier for people to conceptualise and interact with. Secondly, in many cases the institutional arrangements were the only governance mechanisms to which interviewees and discussants referred. Thirdly, discussions confirmed that institutional arrangements and governance are often used interchangeably whereas in reality SDI institutional arrangements are responsible for a range of functions including governance. Fourthly, SDI governance arrangements are heterarchical with complex, overlapping intersecting interactions with SDI and other Government and industry governance mechanisms.

Finally, the research highlighted that much of the work of these visible institutional arrangements is on ensuring 'institutional interoperability' through the development of developing strategies, policies and licencing and access arrangements. Although these concerns are a critical aspect of SDI development, governance of the technical domain of SDI to achieve information interoperability, the ultimate goal of SDI, was not discussed at any length. This may to a degree reflect the nature of the interviewees and

discussants who were perhaps more engaged in strategic and business concerns, but it also confirms the supposition that underpins this thesis and motivated this research. That is, that governance literature and practice tends to focus on the governance of the institutional rather than the technical domain.

These key findings provided important requirements that informed the development of the conceptual model. These are:

- The need for the model to focus on governance of the technical domain, as this is considered to be a critical gap in current approaches to addressing SDI governance and the technical domain is where SDI success or failure is eventually determined;
- Clearly define mechanisms and processes that are used to exercise governance, in addition to the institutional arrangements which dominate governance discourse;
- Clarify how governance relates to other enabling functions exercised through institutional arrangements

6.4 Key aspects of governance

In order to contextualize the SDI governance model and to address some of the ambiguities around governance identified in case study research (described in the preceding section) a brief description of the key dimensions of governance addressed in the governance model are provided below:

- Governance in relation to other SDI enabling functions;
- Heterarchical governance to reconcile top-down and bottom-up governance mechanisms; and
- The three + one dimensions of governance.

6.4.1 Governance in relation to other key SDI enabling functions

At the heart of the governance challenge is the need to bridge the institutional and collective (community of practice) spaces to enable individual organisations to collaborate in order to build and maintain infrastructures.

Governance steers collective efforts through policy and strategic decision making, and provides a framework for managing decision rights for subordinate levels of (technical) decision-making. Other functions like coordination and management do 'the rowing' (Box and Rajabifard 2009). Agreement on governance arrangements is a precursor to and enables agreements on collective and individual functions such as coordination, administration, management and operations that drive an SDI. These functions and the relationships between them are depicted in, Figure 12 below. These functional relationships and definitions were distilled from analysis of the governance arrangements for case studies SDIs.

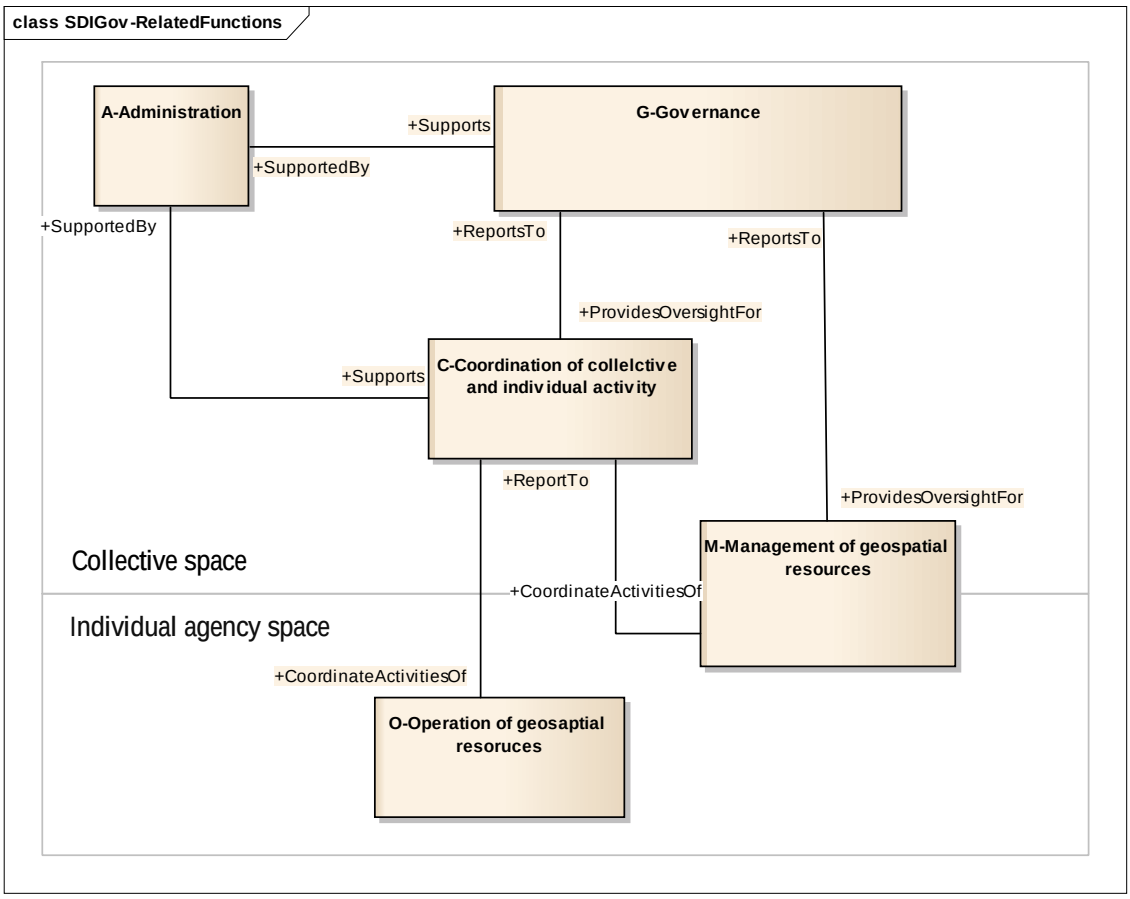

Figure 12 The role of governance in relation to other SDI enabling functions

Key tasks performed by each function and relationships between them, are summarised in Table 5 below.

Table 5 Key SDI enabling functions and their relationships

Function	Key tasks	Key relations to other functions
Governance	• Create and sustain a governance environment; • Ownership of and accountability for the entire initiative (leadership); • Steer the initiative by providing direction and strategic level decisions; • Financial and budget oversight; • Appointment and oversight of leadership; and • Interface with enclosing and related (jurisdictional, domain and technical) governance environments.	• Provide oversight of and direction to coordination and management; • Delegate authority to coordination and management levels; and • Delegate decision making responsibility for each component defined in the system architecture.
Coordination	• Oversee and supports the implementation of governance decisions; • Ensure the activities of individual agencies are orchestrated to achieve a cohesive functional whole; • Lead the stakeholder management process; • Define system architecture and implementation phases; • Oversee the design of key behaviours of system components; and • Provide conformance testing capabilities for technical specifications.	• Execute activities and tasks delegated by governance; • Delegate and coordinate activities to management, operational and administrative functions; • Act as decision authority for decisions delegated to it; • Provide programme and project management; • Coordinate conformance tests for technical capability; • Monitoring and reporting to governance; and • Finance and budget management
Administration	• Provide a secretariat function providing administrative support to maintain collective environment; and	• Supports governing and coordination functions to create and implement

	• Provide communications and other logistical support for the collective environment.	decisions.
Management	• Plan, supervise, direct, control, resources that constitute SDI capabilities or that are used to create, maintain or operate them.	• Provide oversight for operations functions; • Monitor and report to coordination and governance functions; and • Execute conformance tests
Operation	• Build, test, operate, maintain SDI capabilities.	• Report to management; • Interact with coordination function and via coordination with other operations in other organisations.

6.4.2 Heterarchical governance – reconciling op-down and bottom-up governance

SDI governance has in the past been typified by top-down, centrally-driven governance mechanisms that have evolved out of geospatial coordination efforts. Today, it is recognised that governance including that of SDI also has a bottom-up, self-organising, networked dimension. These overlapping, co-existing patterns of complex relationships that characterise SDI governance reality are heterarchical.

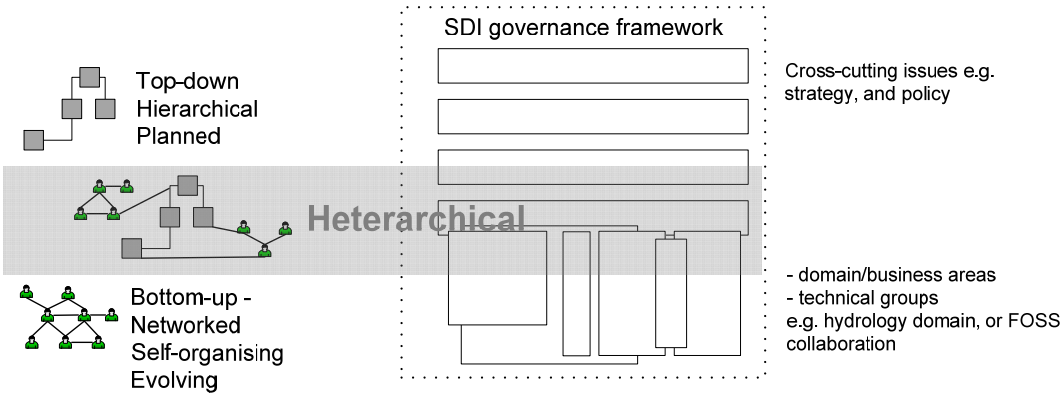

Figure 13 Heterarchical SDI governance - interwoven top-down and bottom-up and governance mechanisms

Figure 13, illustrates that the higher-level strategic cross-cutting issues are typically addressed through top-down hierarchical structures. Bottom-up, self-organising networked governance typically operates at lower levels and develops organically to address specific community identified challenges and may have variable scope and overlap. Initiatives and groups that commence as self-organised networks may become embedded within hierarchical, structured, top-down mechanisms.

In reality, governance mechanisms are heterarchical i.e. an interwoven mix of the two approaches (as shown in the shaded area of Figure 13). This is inevitable as SDI leverages autonomous systems, including sub-SDI, and yet adheres to common standards to enable integration of those resources into a broader community of practice.

In common with the discourse in public governance, given the coexistence of networked governance mechanisms that typify bottom-up approaches and the hierarchical political and regulatory governance models in which they are embedded, it is clear that one of the key challenges of SDI governance is the need to reconcile the twin goals of collective utility embodied in top-down specification and autonomy that allows organic growth driven by the actual capacity of the community. This is borne out in the case studies in which the need to have a balanced part planned and part evolving approach to SDI implementation.

Practically, integration of the two modes of governance occurs through different mechanisms for the social and technical SDI concerns. For example:

- 'social integration' – top down authorisation/delegation and representation e.g. a formal hierarchical governance body authorising and delegating responsibility to make or implement decisions to a network and a network being formally represented in a hierarchical structure by a representative of the network; and
- 'technical integration' – for example mediated federation (or harvesting) of geospatial resources created through bottom up community processes into structured, hierarchical, formally governed top down registers.

In the second case, expert analysis is used to determine how to map the "bottom up" outcomes that meet the needs of a community into a coherent more broadly applicable

model. This process has been partially successful with relatively structured discovery metadata, but is otherwise limited to case-by-case integration of resources. A resource that requires such mediation that is not already mapped to a common model cannot form a predictable part of an infrastructure, since the ability to use it for any purpose is essentially undocumented. As better organised communities emerge, mediated approaches can be limited to bridging entire infrastructures rather than the costly process of designing, building and testing a semantic bridge for every individual resource.

6.4.3 The "three-plus-one" dimensions of SDI governance

Governance is a system at the heart of an SDI. It comprises the rules, policies and mandates, institutional framework, processes, and tools that enable a community to develop, manage and communicate agreements and their implementations in the form of geospatial resources in the form of technology and data.

Conceptually, SDI governance can be characterised as having 'three + one' dimensions as depicted in Figure 14 below. This perspective on governance is based on Rajabifard & Williamson (2001) model of SDI conceptually recast to emphasise the role of governance in enabling cohesive evolution of the SDI components. The dimensions are:

- **the who** – the key roles and relationships betweens of stakeholders and the collective organisational structures through which governance is exercises and in which they are embedded;
- **the what** – the scope of SDI resources under governance ;
- **the how** – the mechanisms and processes to create, manage and support the implementation of agreements that tie together individual and collective efforts; and
- **the when** – the cross cutting temporal dimension related to the evolving scope of governance.

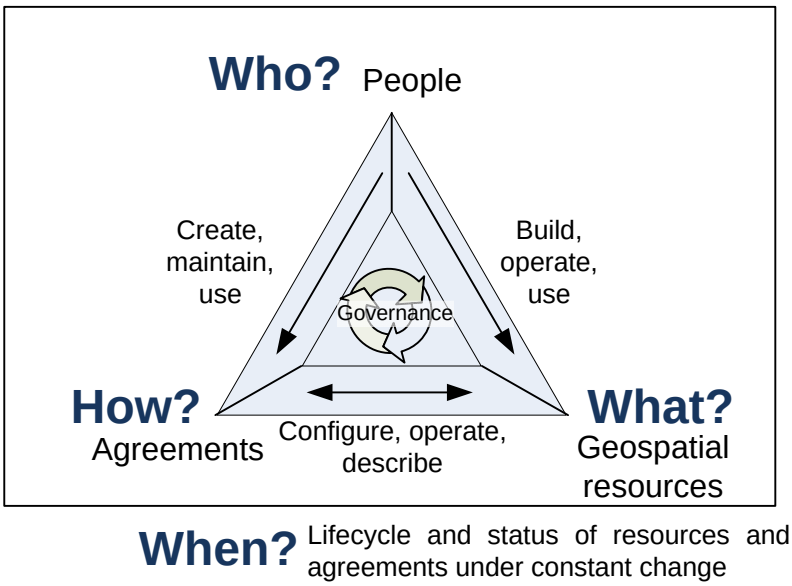

Figure 14 The three + one dimensions of governance

Evolution is an important principle for the governance model as community expectations will evolve as basic challenges of data accessibility are addressed, and more practical uses for data emerges and the infrastructure matures. In a distributed system trust must be established between provider and subscriber through publication and reliable use of published artefacts. However change is a constant and thus there are many possible drivers for a provider to change a service offering. These include:

- Business – changing business context and requirements;
- Technology –changing implementation technologies;
- Service infrastructure - change in type of services available service protocols etc;
- Service lifecycle - services progress from experimental, via testing to guaranteed services, and eventually may be deprecated and retired; and
- Data – new and changed data sets.

Change introduces a cross-cutting concern that lies at the heart of the governance model: “when”. Who, what and how are all subject to decisions about implementation phases, and for the infrastructure to behave predictably, a client needs to be able to identify the status of every resource in the context of a process, and the stability of that resource. This “three + one” view of governance requires transparent process and status information to be an integral part of an evolving SDI. The technical governance of an

SDI becomes more than a one-off design process; it becomes a primary source of information within the system. As such, there is an explicit requirement to link the governance model and the information model of an SDI.

SDI governance is an ongoing process that steers collective efforts. Governance must respond to internal and external changes through the creation, review and modification of agreements. As shown in Figure 15 below, this is achieved through the evaluation of inputs from monitoring both the external environment and internal SDI progress/performance. Evaluation of external and internal conditions provides a context for ongoing decision-making leading to agreements and actions.

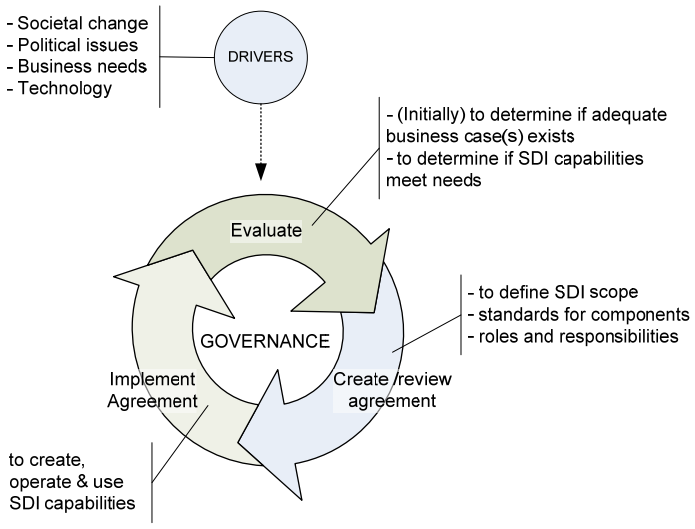

Figure 15 The agreement cycle

6.5 A registry-based SDI governance model

The SDI governance model presented in this section is a registry based approach to governance that focuses on the geospatial resources i.e. the SDI capabilities that need to be designed, created, operated and used in accordance with common agreements. In general, these are the technical aspects of SDI, such as data, services and software components which, if not developed and operated in accordance with standards, will significantly impact the ability of components to interoperate within an SDI.

6.5.1 SDI governance principles

The principles guiding the development of the SDI governance model (derived from the Wisconsin State SDI governance principles in Section 4.8.2) are that governance solutions should be:

- Based on standards;
- Consistent with existing information infrastructure governance approaches;
- Commensurate with the scale of an SDI initiative, the volume of geospatial resources comprising the SDI and thus the scale of the governance challenge;
- Scalable and evolvable;
- Focused on the technical aspects of the SDI, namely agreements and their instantiations in the form of geospatial resources - geospatial data and services;
- Able to assist in reconciling the bottom-up and top-down governance processes and mechanisms that operate within the context of SDI initiatives as well as the broader governance realities within which SDIs are situated; and
- Able to address complex independent change of multiple interrelated resources.

6.5.2 ISO 19135 - Procedures for registration of geographic items

The SDI governance model is based upon the ISO 19135 standard - Procedures for Registration of Geographic Items (ISO 2004). The standard articulates the use of registers (or lists) and registries (the systems that manage these lists,) a set of defined roles to establish and manage the registers, and a registration process to manage the registration of geographic items. As such, it provides a very simple yet extensible and powerful mechanism to implement the governance of technical artefacts in the context of SDI. Furthermore, 1SO 19135 is embedded within the ISO standards suite that provides an interoperability framework for SDI implementation. The standard references and has been developed in the context of other ISO standards that guide the development of technical artefacts such as application schemas, feature type catalogues, and metadata documents. Thus the governance model implicit in this standard is firmly situated in the standards framework and has been designed for interoperability with other standards in the suite. For these reasons, it has been selected as the core foundational element of the SDI governance model.

The things that a community cares about, and must manage to ensure the achievement of collective goals, can be conceptualised as a number of registers, or lists of things that represent agreements about what a component is or how it behaves. These include such artefacts as list of information models, a list of organisations, a list of data access services or a list of specifications or standards. Together these artefacts define and describe the collective activity. Registers contain metadata related to the objects/artefacts that enable them to managed, discovered and used to achieve common goals.

Figure 16 depicts roles and their relationships to each other and to register and registry. In this figure, a register has an owner who determines who has authority to make submission to the register, to adjudicate submission requests and to manage the register and the registry on which it is stored. Users are able to access registers and find information that enables them to create, access or use the common components that together constitute the collective system. Using this approach, a governance regime can be developed through the creation and management of registers.

The governance model implicit in this standard can be applied to collective endeavours that need to register, manage, discover and reuse common information artefacts that are critical to the coherence of efforts.

In this model of governance, the registers and the geospatial resources registered therein, define the scope of governance (the ‘what’) the roles such as register owner, control body and submitting organisation define the ‘who’ and the procedures for submission, registration, discovery and (re)use define the ‘how’ of the governance.

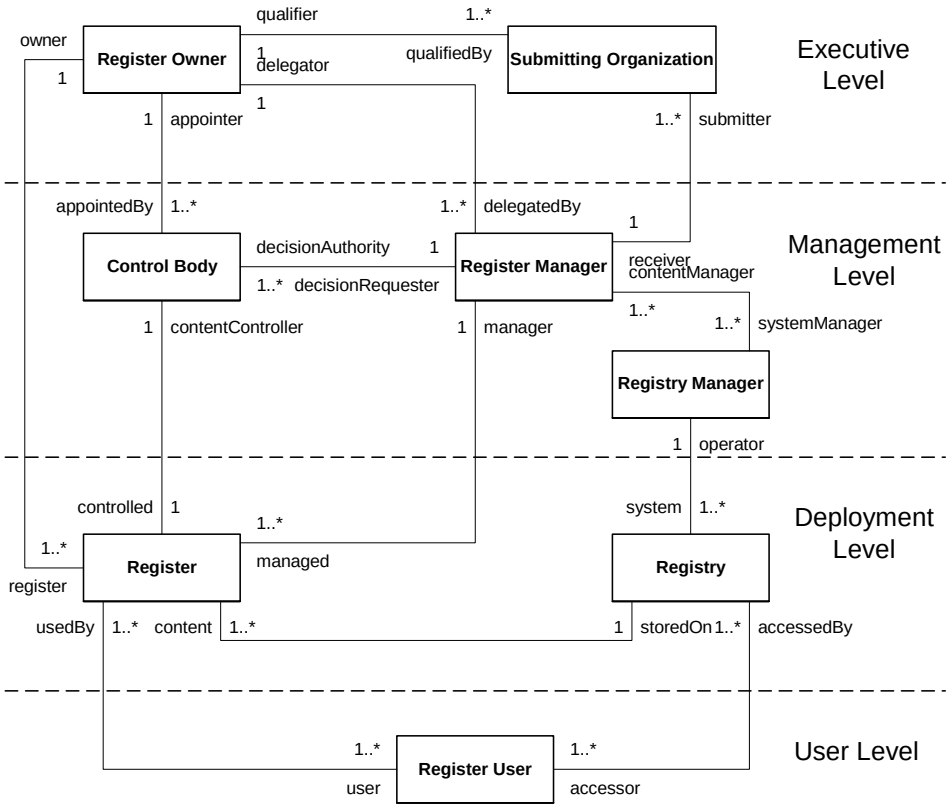

Figure 16 IS0 19135 registers, registries and roles (ISO 2004)

The following section describes the three dimensions of governance, namely what, who and how (from the dimensions of the "3+1" model described in Section 6.3.3.) and maps relevant aspects of the ISO model to each of the dimensions:

- The What – this dimension addresses the scope and portioning of governance using registers;
- The Who – key roles and relations required to exercise technical governance i.e. make decisions and support participation; and
- The How – the processes for assigning and managing decision rights and for managing and publication of decision artefacts that describe collective agreements.

The 'when' viewpoint represents the continually evolving business, technology and data contexts in which the SDI exists and is explicitly addressed through the ability of registers to be added and the key change management function of the register.

6.5.3 The what – governance scope

For the purposes of this model, governance has been partitioned into the following elements, as depicted in as depicted in Figure 17:

- An institutional governance framework – essentially organisation arrangements and authority structures; and
- Two domains of governance with scopes related to social; and technical concerns.

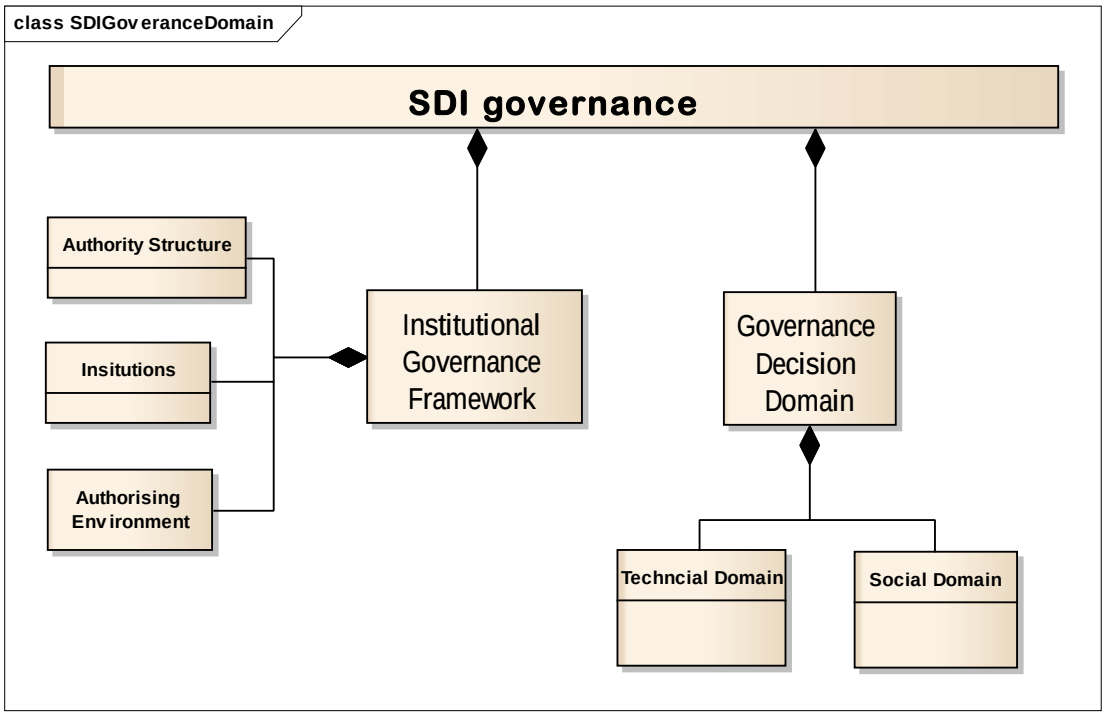

Figure 17 SDI Governance framework and socio-technical governance domains

The institutional framework comprises the institutions, authority structure and authorising environment required to govern an initiative. Within this institutional framework there are two main decision domains. The socio-governance domain, which deals with decision-making related to the cohesion and direction of the SDI including: the governance environment and institutional framework; strategic direction; and policy and business decisions. The technical governance domain deals with agreements relating to design, operation, and use of the technical components – the geospatial resources - of a functional SDI. This approach is informed by the infrastructure perspective of SDI which recognises that they are inherently socio-technical endeavours (Bejar, Latre et al. 2009).

6.5.3.1 Governance of the technical domain

The focus of the SDI governance model is on the technical governance domain. This domain is concerned with management of geospatial resources which are technical artefacts. These artefacts are of two related types. Firstly, there are agreements - about how a geospatial resource behaves such as an information model, a service specification, or an organisation's role in relation to a resource. Secondly, artefacts are the geospatial resources themselves i.e. the things that are implemented and thus represent realisations of agreements. Examples include a web service or piece of software that complies with a standard, or a geospatial dataset that complies with a specific information model or portrayal or format standard. In Figure 18 below, which depicts these relationships, a geospatial resource is traced to the ICA SDI model (as discussed earlier in Section 2.4) concepts of an SDI:Product and SDI:metadata.

A critical aspect of governance is the responsibility to ensure that agreements and the resources that represent their implementation, are registered, related, published, and rendered discoverable. This enables the agreements to be reused during run-time for the creation, management and evolution of the technical capabilities of the SDI that need to interoperate.

In practical terms, the registration process is about metadata. The ISO 19135 standard defines an information model for registers and for registered items focused on capturing and management of registration metadata. The registration process generates metadata about each item registered ('registered item') including its status.

This metadata supports the change management, discovery and reuse of the artefacts be they documents that describe agreements or resources such as data access services or data products that realise the agreements. The artefacts themselves may be published and managed using different approaches. However, these will typically involve the use of some form of registry. For example agreements related to community strategy or policy may be managed using a content management system but these systems use registries to manage metadata that support document management, visibility, discovery, access and use.

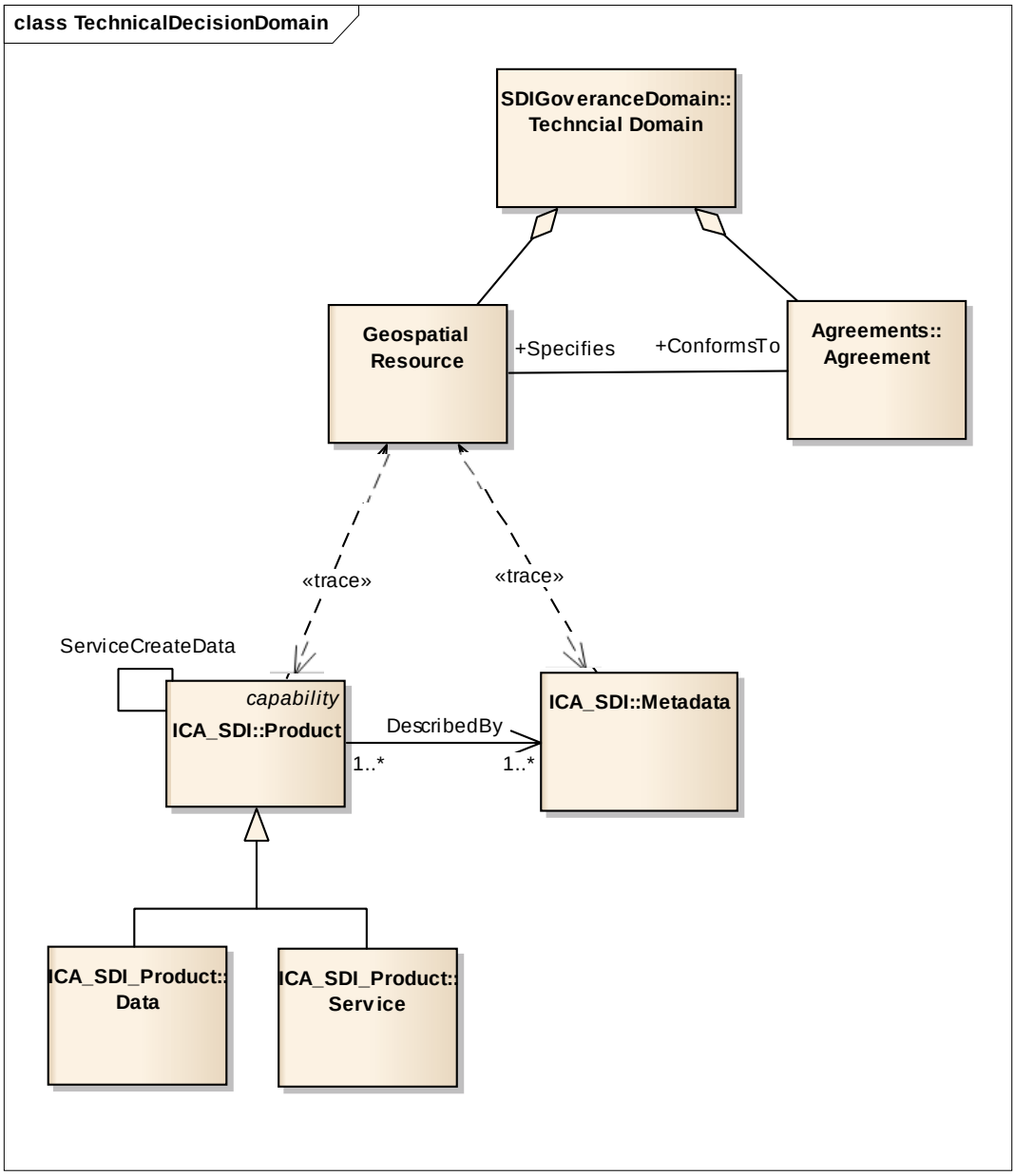

Figure 18 SDI Governance - technical decision domain

6.5.4 Governance roles (the who)

ISO 19135 defines a number of roles involved in exercising governance through the creation and management of registers. These roles are:

- **Register owner** – owner of register, responsible for its intellectual content and the ultimate decision authority for assigning roles related to register governance;
- **Register manager** – responsible for managing the register together with decision authority with regard to register submissions;

- **Submitting organisation** – members of the community able to submit registration requests;
- **Control body** – an advisory body that may be appointed to adjudicate on submissions to the register; and
- **Registry manager** – responsible for managing the registry on which one or more registers are stored.

The process of assigning these roles is one of the key governance processes covered in the next section.

6.5.5 Governance processes (the how)

At the core of this approach to governance are three key processes;

- Register definition and creation;
- Assigning roles related to ownership and management of registers as depicted in Figure 16; and
- The registration process.

The following section describes the three processes of register creation, role assignment and registration in more detail.

6.5.5.1 Register creation

The identification of required registers, their purpose and scope effectively partitions the governance problem space. Top-level registers are organised around specific types of artefacts and sub-divided and scoped to reflect governance realities i.e. who is responsible for what. For example, an initiative might establish a register of vocabularies. This top-level register could be sub-divided into sub-registers with one register relating to each domain authority responsible for managing one or more vocabularies. Sub-registers can be hierarchical or can be implemented as partitions of a single register. In the case of the former, the parent register contains a list of the sub-registers.

In addition to the creation of sub-registers it is possible to define and create relationships between registered items in different registers. Through this mechanism it is possible to build sophisticated governance capability that is able to analyse the impact

of decisions about a resource registered in one register e.g. a community agreed application schema with related resources registered in another register e.g. the SDI web services that delivering information conforming to the application schema.

6.5.5.2 Assignment of roles

Following the identification and scoping of registers, the process of assigning roles related to the registration process is undertaken. This process involved determining who is responsible for the intellectual content of each register, who has decision rights associated with each register and who will manage each register and registry (an administrative function).

The role assignment process relies on the formal authorisation and delegation of authority for various aspects of register management to an initiative's stakeholders. Specifically, the process revolves around the delegation of authority by the register owner. Implicit in this model, is the notion that there is an owner of a notional register the scope of which is the entire initiative. This notional owner role is performed by the peak governance body of an SDI.

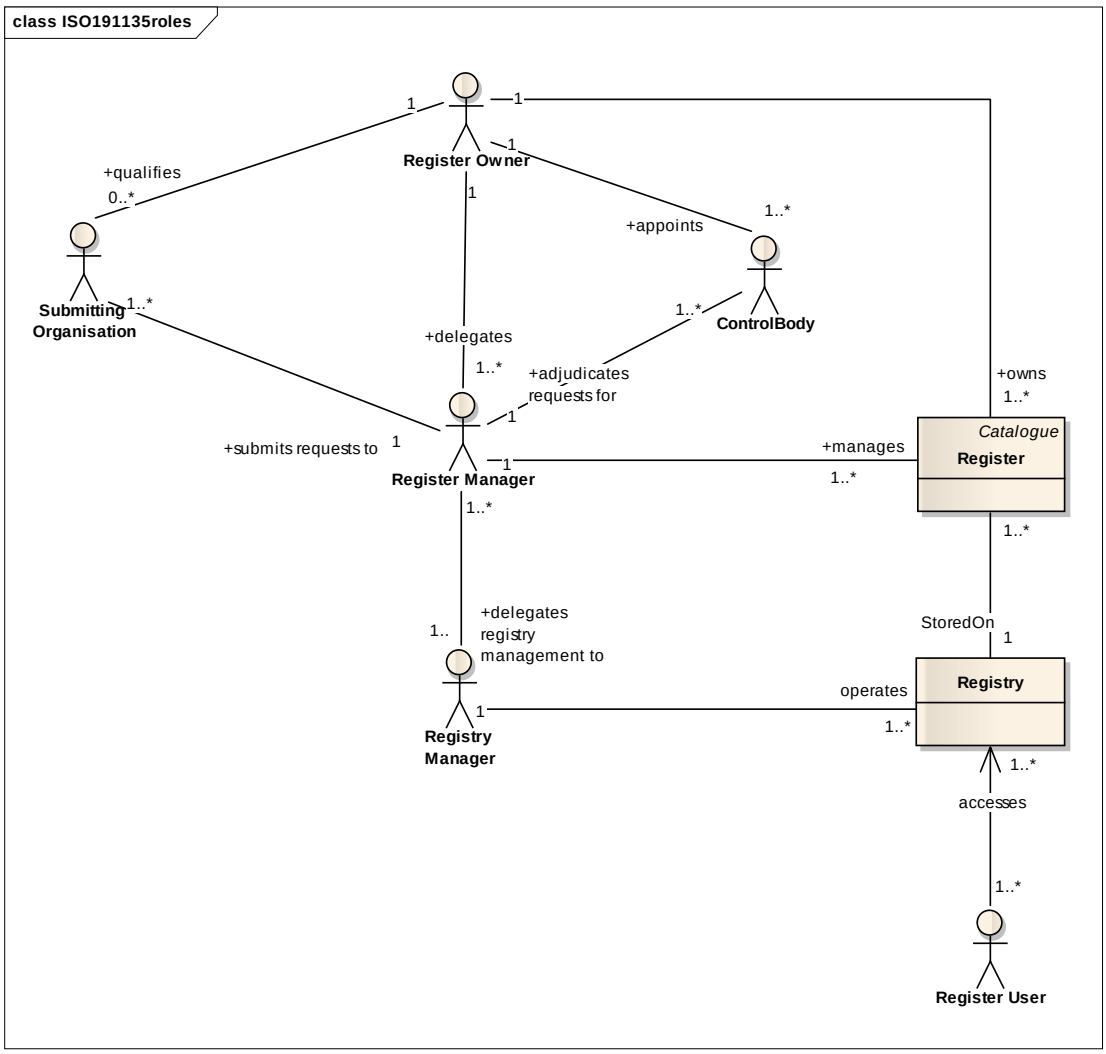

Figure 19 Assignment of governance roles

In Figure 19, which depicts governance roles and their assignment, authority and decision rights are assigned (typically by the register owner) to other roles. Key assignments are:

- **Submitting organisation** (qualified by register owner) – establishment of criteria for organisations that are able to submit items for registration. This process established decision input rights for stakeholders. The criteria determine the inclusivity and degree of participation of the community in the intellectual content of the register;
- **Register manager** (delegates by register owner) – an administrative function and also decision making role in the absence of a control body (delegated responsibility to manage the register and possibly decision authority with regard to submissions);

- **Control body** (optionally delegated by register owner) – an advisory body to adjudicate submission. The control body has decision authority over the register with regard to submission requests; and
- **Registry manager** (optionally delegated by the register manager) - responsibility for managing the registry system upon which the register is stored.

6.5.6 Registration process

The registration process and the registration roles are the central mechanisms that enable governance in this model. The activity diagram in Figure 20 below, based on the workflows defined in ISO 19135 presents these activities. The vertical 'swim-lanes' shown on the activity diagrams represent the different roles involved in these key process. The process revolves around the submission of requests to change, delete or add registered items to a register, the adjudication of submission requests (by the control body) and the adjudication of appeals in the case of contested decisions related registration. The register information model provides sufficient information to track the status of submission and the lifecycle of registered items.

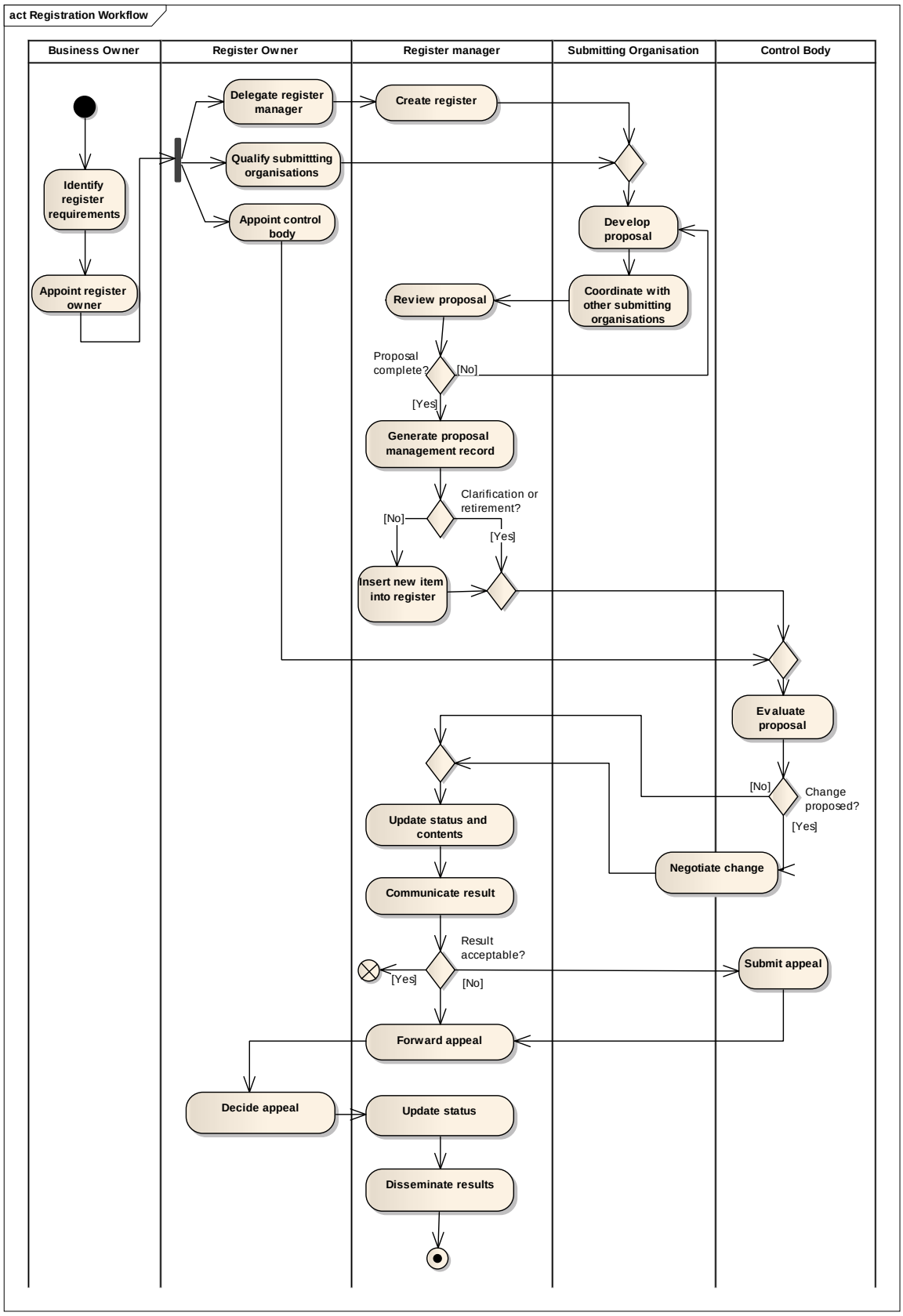

Figure 20 Register creation and registration workflows

6.6 Chapter summary

This chapter has presented an SDI governance model. The chapter has described the approach to developing the model, identified several key underlying concepts related to: the nature of governance as function in relation to other SDI enabling functions; the three + one dimensions of governance; and the heterarchical nature of governance realities. The chapter then presented a model of SDI governance focused on the technical decision domain and the registration of agreements and geospatial information resources that realise these agreements and which collectively comprise an SDI.

The SDI governance model is based upon and conceptually extends the use of the ISO19135 Procedures for Registration of Geographic Information Standard, proposing the use of consistent registration mechanisms for geospatial resources and agreements upon which they are based. Three key dimensions of SDI governance are presented in the model; the what – the scope of governance; the how - mechanisms and processes to support governance; and the who - stakeholders and their roles.

7. Discussion

7.1 Chapter overview

This chapter discusses some of the key aspects of the SDI governance model presented in the previous chapter, relating to delegation and representation, federated governance, the role of registries in mediating top down and bottom SDI implementation and thus addressing heterarchical governance environments. The chapter briefly discusses the application of the model both from a theoretical and a practical perspective.

7.2 Key aspects of the model

The registry based approach to governance articulated in this thesis provides simple but extensible and powerful governance capabilities. These are briefly discussed below.

7.2.1 Delegation and representation

The delegation of authority for aspects of register management and the assignment of decision rights are key mechanisms that determine the level of inclusivity of decision-making. Thus, it is possible for a register owner to appoint a control body. The control body has decision rights over the register and is responsible for the intellectual content of the register. In addition, the register owner determines criteria that determine if an organisation qualifies to make submissions to a register for the addition of new, or the deletion or amendment of existing, registered items. These appointment and qualification processes determine decision rights for a register namely, decision authority for control bodies, and decision input for submitting organisations.

As information communities comprise large and varied groups of stakeholders, representation is critical to inclusive governance. Any of the roles articulated in the governance model could be performed by a representative nominated by a group of stakeholders. Thus a register owner role could be performed by an organisation mandated by and representing, a group of stakeholders. Likewise, a control body may comprise a number of representatives of larger groups. The composition of a control body can be varied to achieve a desired level of participation with participants qualified in relation to the scope and purpose of the register. In most cases, it is anticipated that

registers will be used to register technical artefacts. Thus, the adjudication of submissions would be undertaken by a control body comprising technically-oriented stakeholders rather than ones that represent a socio-political perspective.

In the context of hierarchical, multi-thematic SDIs, in which it is not practicable for a large number of stakeholders to be physically present at decision making fora, these delegation and representation mechanisms enable transparent, extensible governance that supports broad, inclusive participation for large numbers of stakeholders, addressing some of the well articulated needs of SDI governance.

7.2.2 Sub-registers and federated governance

Registers can be hierarchical, with a principal register subdivided into sub registers. Partitioning of registers can be based on territorial jurisdictions i.e. geographic partitioning, or defined information domains i.e. thematic partitioning. In both cases, partitioning is based upon identified governance realities. For example a register of places names representing a global gazetteer could be partitioned into sub registers each of which represents a national gazetteer. Furthermore, each national gazetteer register could be subdivided according to be different feature types comprising the national gazetteer, for example topographic feature names (governed by a national mapping agency), and populated place names (governed by a national census authority). The creation of hierarchical sub-registers together with the ability to delegate responsibility for managing the intellectual content of sub registers to other organisations provides an extensible federated governance model.

7.2.3 ISO 19135 – a heterarchical governance mechanism

An important requirement for any governance solution is the ability to reconcile the ubiquitous, top-down, traditional, and formal institutional governance mechanisms with innovative emergent collaborative bottom-up governance realities such as crowd sourced volunteered community initiatives. The registry-based approach to governance articulated in this thesis is considered to be at the nexus of these two coexisting and interwoven models of governance and thus meets the needs of heterarchical governance realities.

Register identification and management is handled through traditional top-down formal authority structures which enable communities to agree to establish particular registers for specific purposes with a well defined scope. Requirements to establish additional registers driven by broad participation on collaboration at the grassroots level can also through formal governance mechanisms lead to the establishment of a required registers. Once registers are created and the decision input and decision authority for the registers assigned, intelligent content of the registers is determined through broad inclusive participatory networked collaboration.

7.3 Theoretical application of the SDI governance model

The governance model presented in this thesis is intended to provide a conceptual framework for a governance solution that can be integrated with a technical solution that implements ISO 19135 or a similar registry based approach to governance. Thus the model represents an integrated socio-technical governance solution, comprising a technical framework to support submission, management and use of resources together with roles and processes that can be readily mapped onto and performed by individuals in organisations.

The model builds on a suite of ISO 1900 standards and assists in promoting a consistent publication and discovery mechanism within SDIs. If adopted across initiatives, the registries become interoperable. Alternatively the model can be applied at a purely conceptual level to assist in partitioning an initiative's governance problem space and articulating governance roles and responsibilities. It is possible that a mix of the two is used i.e. a registry for technical governance but not ISO 19135 compliant and roles as per ISO 19135. For example, ISO 19135 was used as a conceptual framework to address the requirements for governing shared information and functional components to support the use of a scientific workflow engine for hydrologists (Box 2010).

7.3.1 Application to the social and technical decision domains

In terms of scope, the model is considered to be most applicable to the governance of issues in the SDI technical domain. An issue can be regarded as technical governance issue if there is a technical artefact that must be governed. In this context, a technical artefact either specifies an agreement about how some aspect of a component will

behave or is a component that is based on or implements an agreement (Atkinson and Box 2007). However, it could be applied to other aspects of collective decision making in the socio-decision domain (e.g. data access policies or business plans). However, the choice of governance models for the socio decision domain will be largely influenced by prevailing organisational realities and authority structures established to exercise governance.

7.3.2 Lightweight, scalable and resource-centric approach

The SDI governance model is focused on enabling the creation, registration and ongoing change managements of geospatial resources that comprise an SDI, together with the agreements that are used to inform their development and also act at *post hoc* documentation of developed resources.

The approach does not focus on the institutional framework but on mechanisms to ensure that geospatial resources comprising an SDI that are typically developed and maintained independently, are coherent and interoperable. This resource-centric approach ensures that the governance is lightweight and commensurate with scale of the SDI, and volume of geospatial resources under development and operation. The approach can be scaled to support any number of stakeholders and can be federated to support discrete yet inter-related information communities.

7.3.3 Cross domain and inter-SDI interoperability through reuse

The ability to federate registers which are governed by different communities and managed within discrete registries offer significantly improved prospects for achieving interoperability within and between SDI and information communities (domains) whose needs the SDI is intended to meet.

The ability to discover geospatial resources together with the agreements that provide what is in effect rich metadata about the syntax and semantics of resources, will assist in promoting reuse and thus achieving interoperability across SDI initiative. For example, a user accessing an SDI may discover a spatial dataset created and maintained within the context of a particular SDI. The user may be sourcing a particular spatial data set for use in application under development or may be involved in developing services to deliver similar content in a different context e.g. a different jurisdiction. With an

integrated approach to governance and management of geospatial resources and agreements, both users would be able to discover and potentially reuse agreements such as the GML application schema (defining the structure of information delivered via a Web Feature Service) and the UML information model describing the structure and semantics (e.g. feature types and controlled vocabularies) of content being delivered. For the application developer this ability would greatly enhance her ability to interact with the data and develop an application that correctly interprets the semantics of the data. In the latter case, the agreements available to the geospatial resource developer provide significant resources which can be thought of as reusable design templates to guide the development of similar services. This will greatly reduce cost and time associated with the design of interoperable services, and at the same time greatly enhance prospects for interoperability, as consistent semantics are (re)used across jurisdictions.

7.4 Application in practice

7.4.1 Overview

Beyond the spatial community, the approach implicit in this model is commonly used in a variety of collaborative web based resource sharing initiatives. Several examples include Flickr and Open Street Map. In both cases, successful, large-scale, web based collaborative data sharing arrangements have been established. In the case of Open Street Map, collaborative content creation on a massive scale has been achieved through the establishment of a technical framework that enables contribution with the exact nature of the contribution i.e. geographic location and nature of features, open to individual community members. In this context, the technical framework (platform, technology and information model) provides the top-down structures that enable the provision and creation of content. In both cases, the content that is submitted is not prescribed by the initiative.

Currently, SDI best practice related to the sharing of information resources is represented by the use of catalogues to publish and manage information about data and services. To a lesser extent, registries, essentially catalogs with clearly defined

governance, are used. The following sections describe current best practice with regard to the use of registries in SDI as a tool for governance of geospatial resources.

7.4.2 International Hydrographic Office

There are several emerging examples of large scale registry based approaches to governing common technical artefacts for information communities. One such example is the International Hydrographic Office (IHO), which, to support the creation and management of the S-100 series of data products established a collection of registers to govern a range of common artefacts including types, metadata, symbols and feature types agreed by the community (Ward, Alexander et al. 2009).

7.4.3 Infrastructure for Spatial Information in Europe (INSPIRE)

In Europe, the Infrastructure for Spatial Information in Europe (INSPIRE) is establishing a framework of registries and registers to manage, organise and govern a range of common information resources including feature types and code lists (Schade and Lutz 2010). Shade and Lutz (2010) highlight in particular the role of registers in the governance of Uniform Resource Identifiers (URIs) that enable the unique identification of resources both within and across SDI as part of efforts to establish connections between online resources as part of linked data approaches. von Dömming (2012) reports on the use of registers in INSPIRE to govern a range of geospatial resources. These registers are primarily used to support organisation, maintenance and delivery of information describing the semantics and structure of geospatial information i.e. the agreements) rather than the geospatial information itself.

The ISO19135 registration roles, processes are a critical governance tool for INSPIRE enabling assignment of and responsibility for managing information related to 34 spatial data themes across a significant number of stakeholders in the 30 plus member states of the European Union.

7.4.4 Evolvable information models and Solid Ground

The geospatial, resource-centric registration and governance approach articulated in this thesis is at the heart of approaches to designing and implementing scalable and evolvable SDI being undertaken by CSIRO (Atkinson, Box et al. 2010, Lemon, Atkinson et al. 2011). Approaches to designing and importantly enabling the evolution

of information infrastructure are being implemented through the development of UML modelling tools and methods collectively referred to as Solid Ground.

The Solid Ground approach, aims to leverage existing standards and apply model driven architecture (MDA), embedded within well articulated governance arrangements to achieve interoperability within and between large scale information community developers. This is achieved through the use of modelling tools that enable the creation of modular information models, and a registry used used to store and manage modular information models which implements ISO19135 (Francis, Murray et al. 2012). As in the case of INSPIRE, registers of semantic resources (generated from UML information models) are increasingly being used to deliver information to end users. For example Atkinson Cox et al. (2012) describe the development of a feature type catalogue that enables the linking of semantic elements described in the registered UML models of geospatial information resources.

7.4.5 UNSDI Spatial Identifier Reference Framework

A geospatial resource centric and registry driven approach to governing SDI technical resources is being implemented in the UNSDI Spatial Identifier Reference Framework Project (formerly the UNSDI Gazetteer Framework Project) (Box, Kostanski et al. 2012). The project aims to improve access to, and integration and use of information required for social protection and poverty reduction held in different systems through the development of a framework – the Spatial Identifier Reference Framework (SIRF). SIRF is suite of interrelated infrastructure components used to register, manage and deliver spatial identifiers as linked data.

Spatial identifiers such as postcodes, place names, administrative unit codes, or asset numbers are contained within most geospatial dataset and are used extensively to reference and integrate information contained in different systems. Identifiers carry more semantics than geographic coordinates, including for example multiple names in different languages, feature type information and geometric representations of the location of real world features. However, spatial identifiers and in fact the underlying spatial dataset from which they are derived are poorly governed. For instance, versioning of datasets and change management at a feature instance level is poorly

managed, and there is a lack of clarity around who has the authority to create a representation of a real world feature or create an 'authoritative' identifier for it.

SIRF aims to provide stable identifiers using a scalable governance model, and the means to discover and access alternative forms of representation of object delivered through spatial data infrastructure (SDI) services. It provides a registry-based governance mechanism that supports the registration and cross-walking of multiple references to places held in different datasets. Information models describing heterogeneous source dataset are registered and used to transform the features harvested via Web Feature Services into a common structure and semantics. The harvested features (i.e. geospatial resources) are delivered as linked data, together with metadata captured at registration and extracted from agreements e.g. UML models and data licences related to the harvested data sets.

SIRF is designed as a globally scalable framework as part of a UNSDI standards and best practice activity (Box, Atkinson et al. 2012). Thus, the registry based approach is intended to scale up to address global scale SDI governance challenges, for example reconciling and eventually rationalising the multiple feature type catalogues that are in use within each information community (Kostanski, Atkinson et al. 2012).

7.5 Chapter summary

This chapter has discussed some of the key aspects of the SDI governance model. It has described the utility of a registry based approach as a heterarchical governance mechanism, able to reconcile co-existing top down hierarchical governance and bottom-up networked governance, as well as being scalable across initiatives using a federated registry pattern. The chapter has also discussed the application of the model in both theoretical terms as well as from a practical perspective, highlighting real world examples of the application of registry based approaches to governance.

8. Conclusions

8.1 Introduction

Governance is a central concern of SDI enabling collaboration to achieve collective goals of stakeholders. Despite the recognized importance of governance, there is a lack of consensus about key concepts. Furthermore, there has been relatively limited research into SDI governance challenges and potential approaches to addressing them. Without a sound theoretical basis for understanding governance, it is not possible to develop appropriate, scalable, broadly applicable SDI governance solutions.

This chapter provides a brief review of the motivation for this research together with key research objectives. The chapter then provides a synthesis of research findings and the contribution of these findings to the field and concludes with recommended future research opportunities.

8.2 Research objectives

This research has been motivated by a desire to contribute to solving what been identified as one of the critical barrier to SDI implementation, namely SDI governance. The specific objectives of the research are to:

1. Explore governance in a variety of contexts to review potentially applicable governance principles, theories and models for developing a conceptual framework for understanding SDI governance;
2. Evaluate current research into SDI governance to determine current understanding;
3. Explore SDI governance challenges in practice, using a mixed method, case study based approach and extract common principles, patterns and critical elements that are broadly applicable to inform the development of an SDI governance model; and
4. Develop a model for SDI governance that articulates key governance concepts, processes and relationships.

Each of these objectives is briefly addressed below.

Objective 1 – Explore governance contexts

In chapter 3, governance in a range of contexts including those of public governance, drawn from political sciences, corporate and IT governance, were explored. From this review, new modes of governance were identified including multi-level governance from the EU and new forms of heterarchical governance in which networked and hierarchical modes of governance interact. In addition, two important and related IT governance mechanisms were identified. The first was the ISO 19135 Standard for Registration of Geospatial Items, described in chapter 4, which provides a standardized mechanism for governing geospatial information resources and the Decision Rights Framework which articulates a conceptual approach for implementing decision rights related to IT resources. From this review the author developed the following definition of governance:

> ”*Governance is a framework that enables communities to manage their collective affairs through a continuous process of negotiation and decision-making.”*

In addition to providing some important foundational concepts to inform the design of an SDI governance model, an exploration and understanding of broader governance contexts is considered to be important as SDI governance is embedded within and must effectively interact with the broader governance contexts within which it operates.

Objective 2 - Evaluate SDI governance research

A review of SDI governance literature from research and practice was undertaken to determine what was currently understood about SDI governance. Several important insights were gained from this review. Firstly, in the rather limited SDI governance literature, there has been a focus predominantly on institutional arrangements and coordination mechanisms that are established to govern and enable decision making in SDI. The review concluded that the term SDI governance appears to have become synonymous with SDI institutional arrangements and that the governance and coordination functions have been conflated. This thesis proposes that institutional arrangements, such as authority structures are an important aspect of SDI governance enabling collective decision making, but are only a part of the governance narrative. The research further identified coordination as a necessary but distinct supporting

function for governance, providing the critical link between the 'steering' processes of governance and the 'rowing' activities of individual actors that move the community in the required direction. Secondly, the review identified strong correlation between the broader public governance trends such as MLG and the recognition of heterarchical governance models and emerging SDI governance realities.

Finally, from the literature review, it was apparent that there has been little attention given to exploring or defining the requirements for SDI governance i.e. what are the socio-technical concerns that need to be addressed. In order to implement effective SDI governance, it is necessary to understand the nature and scope of the SDI governance challenge i.e. what are the individually and collectively owned and operated resources that need to be governed to effectively implement an SDI. This insight was critical in defining the scope and focus of the SDI governance model namely, the governance of technical decision domain.

From this review of existing literature the author proposed the following definition of SDI governance:

> *"An overarching and enabling decision-making and accountability framework comprising authority structures, roles, policies, processes, and mechanisms that enable collective decision-making, and collaborative action to achieve common goals."*

Objectives 3 Explore case studies and abstract SDI governance principles and practices

Given the variable, complex and intrinsically social nature of the SDI governance, an exploratory case study approach was used to explore the governance of four Australia SDI case studies. In general there was broad consensus about the importance of SDI governance and the nature of challenges. Several common themes related to governance success factors were distilled from the different SDI contexts. These included the observations that: successful collaboration was underpinned by trust developed over time between individuals working together; SDI governance arrangements need to embedded within broader governance arrangements; and that separate but inter-dependent institutional and technical frameworks should be developed for SDI. These

case studies yielded important insights that were used to inform the development of the model.

Objective 4 - Develop an SDI governance model

A registry based model for SDI governance was presented in Chapter 6 that focused on the technical concerns of SDI decisions making. This was model was based on governance concepts drawn from other fields, a review of SDI governance literature and analysis of Australian SDI case studies. The model was articulated around the 'three + one' dimensions of governance, that is: 'the who'- stakeholders, 'the what' – scope of governance; 'the how' – mechanisms and 'the when' – handling change. Of particular note, in the model is the definition of the scope of SDI governance in terms of an institutional framework and two distinct decision domains covering social and technical concerns. This separation of concerns was based on the critical insight that research into and implementation of SDI governance has to-date focused largely on the socio-governance domain. This domain deals with decision-making related to the cohesion and direction of the SDI including: the governance environment and institutional framework; strategic direction; and policy and business decisions.

By contrast, the technical domain has received little attention. The technical domain is concerned with the governance of agreements about how geospatial resources behave and the realisation of those agreements in terms of geospatial resources such as software components or information resources that actually comprise the SDI. In practice, efforts in the technical governance domain have focused on governance of standards development and adoption processes and service governance in the context of service oriented architecture. There has been little attention paid to the governance of the technical artefacts that underpin interoperability

8.3 Contribution to the field

The key to inter and intra SDI interoperability is enforcing compatible approaches to handling interoperability agreements. This thesis has presented a governance model that aims to achieve this, using a standards based approach comprising the use of registries and registers together with registration processes and associated roles that enable a community to govern shared geospatial resources. The model provides a conceptual

framework for governance of SDI that can be implemented using a technical solution implementing ISO 19135 or a similar registry based approach to governance.

Governance comprises the authority structures that enable decision making together with supporting mechanisms that enable the management, discovery and use of agreements - the outcomes of decision-making processes. These agreements in turn enable SDI stakeholders to create, describe, register, discover and re-use geospatial resources (information and services). The SDI governance model described in this thesis provides the basis for an end to end solution comprising, decision-making, management of metadata relating to agreements and metadata describing the resources that are developed based on those agreements. A consistent registry based approach with rich registration metadata will ensure, transparency, traceability, discovery and reuse of the resources across SDI design time and run time environments.

The proposed approach to addressing governance does not focus on institutional arrangements or authority structures, but on ensuring that geospatial resources that are independently developed and maintained, are done so in a way that ensures their coherence and interoperability. This resource-centric approach enables a lightweight and scalable approach to governance with governance effort commensurate with scale of the SDI.

The ability to discover geospatial resources together with the agreements that provide rich metadata about the syntax and semantics of resources, will assist in promoting reuse and thus achieving interoperability across SDI initiatives. The ability to federate registers governed within different communities, offers significantly improved prospects for achieving interoperability within and between SDI both horizontally across domains as well as hierarchical aggregation of geospatial information resources.

The model is considered to be a valuable contribution not only to improving the quality of governance but to addressing fundamental underlying challenges that SDI implementation is designed to address namely, delivering seamless interoperable information resources for end users.

The model recognizes and addresses the complexity of overlapping involvement of stakeholders in multiple roles around multiple registers in multiple initiatives that exist in practice e.g. an agency in one jurisdiction as member of control body for a thematic SDI in another jurisdiction. The elaboration of governance through the creation and operation of registers represents a formal, top-down hierarchical approach to governance. Assignment of roles for governing and submitting content of registers supports a bottom-up networked community engagement model. Thus the registry based approach enables rather than precludes the interaction of complex interwoven network and hierarchical governance mechanisms i.e. it supports heterarchical governance.

The model extends a paradigm that is well understood within SDI i.e. the use of registries and catalogs for information and services. A degree of comfort and familiarity with this concept is likely to assist in the communication and uptake of this approach.

8.4 Future research directions

This research has presented a model for governance that is intended to inform operational responses as well as guiding further research. The research has led to the development of a model for SDI governance, exploring an intrinsically social phenomenon that is used to achieve geospatial resource interoperability, a technical concern. To complement and extend this work, three main areas of research are proposed; related to exploring patterns of SDI interaction; social network analysis of SDI resources and governance; and governance of semantic resources.

8.4.1 Towards heterarchical models of SDI

A key theme of this research has been the parallels between the emerging trends of public governance and SDI governance and the identification of heterarchical governance models. These models are a response to the nature of interaction between stakeholders in a given domain. The existence of heterarchical SDI governance arrangements therefore implies that SDI themselves are heterarchical. Research to explore the current patterns of SDI interaction to extend existing notions of SDI hierarchy, would be a useful contribution to research. For example studies might be undertaken to explore the way in which key components of SDIs, for example a spatial

web service, a technical standard or an individual performing a governance role in the context of an SDI are involved in other SDIs.

8.4.2 Social network perspectives on SDI governance and geospatial resources

Governance is an intrinsically social function enabling people representing organization to participate in collective activity. Social network analysis (SNA) provides a new lens for understanding how people are connected and how they engage with each other. Two major themes of research are proposed:

1. SNA applied to SDI authority structures – comprising research into documenting formal SDI authority structures, and the roles played by individuals and conducting social network analysis to explore and compare network patterns and measures within and between SDI; and
2. SNA applied to geospatial information resources – the geospatial information resources and components used to enable their discovery and use possibly within multiple SDI contexts are owned and operated by individual agencies. An exploration of geospatial resource-centric patterns of social networks would be a useful contribution to understanding and improving resource governance.

8.4.3 Governing semantic resources

To date, the majority of efforts to address interoperability challenges has focused on the structural or syntactic interoperability i.e. the ability to integrate information in different formats and structures. Geospatial tools are able to handle different formats of geospatial information reasonably well and there has been significant progress in our ability to transform information structures and for communities to develop and use agreed common models or application schemas. So it could be argued that syntactic interoperability challenges are well in hand. The next challenge to be solved in order to integrate heterogeneous information from multiple sources is that of semantic interoperability i.e. dealing with the different meanings definitions used in geospatial information and metadata to describe real world features. For example the use of different road type classification in two states or handling the references to the unit of measure ‘year’ that could refer a calendar or a financial year.

Semantic resources in common with other resources need to be governed so that they can be agreed upon by a community, managed over time, discovered and used for both design time (when developing resources) or run time (when when using resources in operational systems) purposes. Research into governance to understand the requirements and potential solutions for governing semantic resources in a holistic fashion is a significant potential area for research.

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