# Assessing Spatial Data Infrastructures

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Łukasz Grus

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# Contents

# Chapter 1

# General Introduction

# 1 General Introduction

## 1.1 Background

For thousands of years people have had an interest in geographical information. Maps have always been a common medium for presenting and sharing this kind of information. The first mapping practices date back to the ancient civilizations of Egypt (about 3000 B.C.) and Babylon (about 2500 B.C.) (Dilke, 1987). These civilizations used maps made on stones, wood, papyrus and paper. Recently, with the advent of the digital age, map handling has changed from paper to digital forms (Clarke, 2001). This shift has been accompanied by the emergence of Geographical Information Systems (GIS). GIS, besides map making, allows also for dynamic modelling of complex spatial and temporal processes (Chang, 2006). New applications have been made possible by the provision of computing tools, the increasing abundance of spatial data and the enormous diversity of applications offered by modern technologies (Burrough & McDonnell, 1998). However, the internet has enabled the large amount of diverse digital spatial data underpinning the use of GIS to spread across the world and across many organizations in multiple formats. Without addressing the issues of finding, accessing, coordinating, integrating and managing these dispersed and fragmented spatial data, the potential of GIS cannot be realized. These issues can be addressed and realized by Spatial Data Infrastructures (SDI).

SDI is a concept for providing an environment within which organizations and/or nations interact with technologies to foster activities for using, managing and producing geographical data and information (Rajabifard et al., 2003a). This environment usually contains specific policies, technology and standards regulating the access to and use and dissemination of diverse spatial data. Until now many authors have contributed to the popularization of the SDI concept, research and practice (McLaughlin, 1991; National Research Council, 1993; Onsrud, 1998; Groot & McLaughlin, 2000; Rajabifard, 2002; Williamson et al., 2003; Nebert, 2004; Masser, 2005a; De Man, 2006a; 2006b; Onsrud, 2007). At the same time, numerous SDI initiatives have been established on global, regional, national and local levels. Since the discussion on 'spatial data infrastructures' started in 1991 (McLaughlin, 1991; Masser, 2007) over a period of 10 years around 120 countries initiated projects related to establishing SDIs (Crompvoets & Bregt, 2003). An increasing number of countries or regions are working on strategy plans that aim to give the SDI concept a formal character, such as a national law or policy. For example, in 1994 the President of the United States signed Executive Order 12906 establishing a National Spatial Data Infrastructure in the United States (Clinton, 1994), in 2007 the European Union Directive establishing an Infrastructure for Spatial Information in the European Community entered into force (European Commission, 2007), and in 2008 the Dutch Parliament approved GIDEON as the national policy document establishing a National SDI (VROM, 2008).

The increasingly formal character of SDIs also presents new demands for SDI assessment. There is a growing need for stricter and better defined SDI assessments (Bregt et al., 2008). New assessment demands tend to come mainly from the policy makers and politicians who expect to relate the current SDI activities to concrete objectives that they expect to achieve. For example, The Dutch Ministry of Housing, Spatial Planning and the Environment (VROM) has included in the GIDEON document a requirement for progress monitoring of the Dutch SDI (VROM, 2008). In addition, the INSPIRE directive requires member states to monitor and report on implementation of the directive and the use of the infrastructure. Formal and detailed rules on monitoring and reporting on the implementation of INSPIRE by the member states have already been developed (Vandenbroucke et al., 2008a; European Commission, 2009).

## 1.2 SDI assessment and evaluation

Evaluation or assessment emerged as a common professional practice at the beginning of 20th century, mainly in education (to assess literacy and occupational training) and public health (to assess the effectiveness of programmes for reducing mortality from infectious diseases). Assessment practice developed rapidly in North America when considerable federal and private funding was made available to support urban development, technology, culture, education, nutrition and healthcare, among others. The outcomes of these large expenditures had to be identified (Rossi et al., 2004). Assessment has also received much attention in recent years. For example, now that the existing democracies are relatively mature, there is a greater demand for transparent public management and so the use of assessment information in governance has great potential (although not yet realized) for enhancing the quality of democratic debate (Pollit, 2006). Also, in times of limited resources, government agencies have to articulate key programme goals and measure the extent to which programmes meet their goals. This is important to restore public confidence in government (Wholey, 1997).

The terms ‘assessment’ and ‘evaluation’ are defined in multiple ways and are often used in the evaluation or assessment literature interchangeably. In principle, ‘assessment’ refers to a judgement about a person or situation, whereas ‘evaluation’ refers to a study designed and conducted to assess an object’s merit and worth (Choppin, 1991; Longman, 2005; Stufflebeam, 2000). In this thesis, when referring to SDI these two terms will be used interchangeably.

Large sums of money and effort have already been invested in discussing, implementing and operating SDIs worldwide. For example, it is estimated that the implementation of the Infrastructure for Spatial Information in the European Community (INSPIRE) would cost somewhere between €202 and €273 million each year (Cragila, 2003). Besides the necessary financial resources, considerable amounts of time and energy are also required for coordinating, building capacity and implementing SDIs. For example, the debate on establishing an SDI in the European Community took six years, from the moment that INSPIRE was proposed in 2001 until 2007 when the directive was adopted. Given these investments of resources, time and effort, it is increasingly important to focus on assessing SDIs. For example, there is a growing awareness among governments and communities of practitioners that much more attention needs to be paid to assessing the social and economic impacts of SDIs (Craglia & Nowak, 2006).

Many scientists have already been working on SDI assessment theory and practice. In 1998 Onsrud (1998) made an initial worldwide survey of 30 national and 6 multination and regional SDI activities. In 1999 Masser (1999) reviewed 11 National SDIs and assessed them in terms of driving forces, status, scope, access, approach and resources. In 2003 Crompvoets and Bregt (2003) made the first survey of the worldwide status of National SDI clearinghouses – a key feature of SDI (Crompvoets, 2006). In 2004 they assessed worldwide developments in national spatial data clearinghouses (Crompvoets et al., 2004). Meanwhile Steudler et al., (2003) used the assessment framework for land administration systems as a basis for developing evaluation and performance indicators for SDI assessment. In 2005 Kok and van Loenen (2005) published a paper on assessing the organizational aspects of SDIs, and in the same year Delgado et al. (2005) developed a methodology for assessing the preparedness of countries to embrace SDIs. The Spatial Applications Division of K.U. Leuven performed a longitudinal SDI assessment study (SADL, 2005) describing and monitoring 'pre-INSPIRE' SDI initiatives in European countries. Rodriguez Pabón (2005) proposed a theoretical SDI assessment framework, describing SDI success criteria across different contextual backgrounds. Giff and Crompvoets (2008) initiated an analysis of possible tools for measuring and reporting an SDI's performance. The funding processes within SDIs were recently described and assessed by Lance et al., (2008). Finally, Crompvoets et al. (2008a) have edited a book that brings together the latest developments of SDI assessment.

## 1.3 Research gaps

Despite the vast number of scientific publications about SDI and SDI assessment, there are still issues that need further research. The following three research gaps impede SDI assessment research and therefore need to be highlighted.

First, it has already been indicated that SDIs have a tendency to become complex (Chan & Williamson, 1999a; De Man, 2006a; Georgiadou et al., 2006; Masser, 2007). However, few studies have further analysed SDI complexity. As a result, the question of how to deal with this complexity while developing, managing and assessing SDIs remains open. For example, a large number of SDI definitions, which is a consequence of SDI complexity (Chan, 2001; Rajabifard et al., 2003; De Man, 2006a), is one of the major obstacles to SDI assessment. This large number of different SDI definitions reflects substantial differences within the SDI community in the understanding of the nature of SDIs and their potential benefits. Consequently, deciding on uniform criteria against which SDIs should be assessed is problematic (Cragila and Nowak, 2006). Better analysis of SDI complexity is still needed to find solutions to the aforementioned problems.

Second, to the author's knowledge, there is no operational assessment framework that can assess SDIs in a comprehensive way. The existing SDI assessment views concentrate on assessing specific SDI aspects, such as data access facility (Crompvoets, 2006), readiness to embrace SDI in a specific country (Delgado Fernández et al., 2005), or organizational issues (Kok & van Loenen, 2004). Other SDI assessments focus on SDIs in one region (SADL, 2005), compare SDI developments in few countries (Masser, 1999; Onsrud, 1998) or asses specific SDI implementations (Lance et al., 2006). There are also theoretical SDI assessment views that assess SDIs using different contexts, such as social (Rodriguez Pabón, 2005), cadastral (Steudler et al., 2004) or performance-based management (Giff & Crompvoets, 2008). What is missing is a framework that can bring the existing assessment concepts, views and methods together to enable a more comprehensive SDI assessment (Crompvoets, 2006). Such a comprehensive SDI assessment framework also needs to be operational to meet the current SDI assessment demands of different SDI assessment users. Therefore, the practical usability of the framework and its appreciation by potential users should be evaluated before the framework can be considered to be applicable for assessing SDIs.

Third, the majority of existing SDI assessment views, some of which are mentioned above, are rather intuitive in nature and have been proposed by the SDI scientific community (Bregt et al., 2008). However, nowadays there is a growing demand for more rational SDI assessments with generic views that measure, for example, the relevance and usefulness of SDIs (Budhathoki & Nedovic-Budic, 2007) or the extent to which SDI programmes meet their goals (Lance et al., 2006; 2009; Giff & Crompvoets, 2008). In addition, SDI assessment studies have so far mainly had an ex-ante character, focusing on predicted SDI impacts and benefits (Cragila et al., 2008; Cragila, 2003; Dufourmont, 2004). Ex-post impact studies have seldom been done (Lance et al., 2006). It is therefore necessary to complement the existing array of SDI assessments with an SDI assessment view for assessing whether an SDI realizes its intended goals and benefits.

## 1.4 The objective

The objective of this thesis is to develop a comprehensive framework for assessing Spatial Data Infrastructures. The process of developing the framework is divided into four sub-objectives:

1. to analyse SDI complexity;
2. to develop a SDI assessment framework;
3. to evaluate the developed SDI assessment framework;
4. to expand the developed SDI Assessment Framework by adding an assessment view for a goal-oriented SDI assessment.

## 1.5 The scope of the thesis

This thesis develops a comprehensive framework for assessing SDIs. The proposed framework is designed in such a way that it acknowledges and deals with SDI complexity.

The framework has been applied and evaluated only for National SDI (NSDIs) initiatives. The reason for choosing NSDIs was that they are easily identifiable because they are based on a single national vision and strategy and are managed by national steering committees. In addition, it was relatively easy to contact National SDI coordinators and obtain the required data and information. Nevertheless, it has to be stressed that the intention of the proposed assessment framework is that it is generic, in other words, it can also be applied to SDIs on different levels, such as the regional, state and local levels.

The assessment framework was applied to 21 National SDIs only for the purpose of evaluating its applicability for assessing SDIs. The real assessment of SDIs using the developed framework was beyond the scope of this thesis.

The intended target groups of this research are SDI policy makers, coordinators and researchers. Policy makers and coordinators may be interested in applying the assessment approaches and methods to discover the strengths and limitations of their programmes. The assessment results could help to improve SDI performance and measure outcomes. It is also hoped that this thesis will deepen the general knowledge about SDIs and trigger discussion among researchers about SDI components, mechanisms and concepts.

## 1.6 Outline of the thesis

The research activities conducted to reach this thesis objective are described in the following chapters.

**Chapter 2** analyses SDI complexity using Complex Adaptive Systems theory. This investigation is based on case studies of three National SDIs and a survey of SDI experts. The results of the study have implications for the way in which SDIs should be further assessed.

**Chapter 3** develops a comprehensive Multi-view SDI Assessment Framework. The proposed framework is strongly based on theoretical studies on assessing Complex Adaptive Systems and an extensive review of the literature related to assessment and evaluation.

**Chapter 4** evaluates the Multi-view SDI Assessment Framework. The framework was first applied to 21 National SDIs from around the world. The process of framework application and the applicability of the results to assess SDIs are evaluated.

**Chapter 5** expands the Multi-view SDI Assessment Framework by adding a goal-oriented SDI assessment view, which is developed and evaluated. This chapter discusses the method used to develop a goal-oriented SDI assessment view, which was tested by applying it to the Dutch SDI and evaluated by the potential users.

**Chapter 6** discusses the results of the thesis, presents general reflections and limitations on SDI assessment, and presents recommendations for future research.

# Chapter 2

# Spatial Data Infrastructures as Complex Adaptive Systems

Łukasz Grus, Joep Crompvoets, Arnold K. Bregt

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# 2 Spatial Data Infrastructures as Complex Adaptive Systems

## 2.1 Introduction

Over the last two decades, many countries throughout the world have taken steps to establish national SDIs. These actions have sought to provide an infrastructure for accessing and sharing spatial data to reduce the duplication of spatial data collection by both users and producers, and enable better utilization of spatial data and associated services. However, the great variety and large number of stakeholders, their different needs and the complex relations between them make the implementation of SDIs a very complex business. Moreover, the adoption of innovative technologies makes SDI development very dynamic and leads to differences in the architecture of these infrastructures between countries.

Many researchers have tried to apply various theories to describe and better understand the complex and dynamic nature of SDIs. The diffusion of innovation theory has been used by many researchers (Chan, 2001), such as Onsrud and Pinto (1991), Masser (2005a), Masser and Onsrud, (1993), Campbell (1996), Masser and Campbell (1996) and Chan (1998), to illustrate and understand the development and adoption of GIS and SDI initiatives within societies. Rajabifard et al. (2000) used hierarchical spatial reasoning (Car, 1997) to describe the complex hierarchical structure of SDIs. De Man (2006a) applied the concept of institutionalization to explain the linkage between SDIs and spatial data communities and determine how they can be made effective and sustainable. Chan (2001) claims that the perceptions and descriptions of SDIs fail to convey their dynamics and complexity and that therefore a theory is still needed to better understand, describe and evaluate the complex nature of SDIs. Many researchers have indicated that SDI complexity is the main obstacle to its understanding and assessment (Grus et al., 2006). Only when the mechanisms behind SDIs are well explored and understood will it be possible to better develop, manage and evaluate them.

Complex Adaptive Systems theory has been used in many disciplines (e.g. economics, social sciences, organizational studies and biology) to describe and better understand the features, mechanisms and rules of complex phenomena. For example, complexity theory has been used to evaluate the capacity for collaboration in Health Action Zones policy (Barnes et al., 2003) and CAS research is used to assess the best transition paths towards future technological innovations in industry (Franken et al., 2007). In general, applying CAS theory to other domains may help in better understanding of the mechanisms and features of complex phenomena.

This research seeks to determine whether or not Spatial Data Infrastructures can be viewed as Complex Adaptive Systems. We analysed three National SDI cases and conducted a survey on the complex characteristics and features that can be found in SDIs.

The remainder of this article is organized as follows: section 2 describes the complex nature of SDI; section 3 presents the principles of Complex Adaptive Systems theory; section 4 explains the methodology used to meet the research objective; section 5 states the research hypothesis that SDIs can be treated as CASs; section 6 presents the results of the application of CAS theory to the selected national SDI cases (Australian, Dutch and Polish) and the results of the survey of SDI experts on the complex character of SDIs; section 7 discusses the results of the analysis of the case studies and survey responses, presents some implications of these results and makes recommendations for further research on exploring and evaluating SDI; section 8 describes the conclusions of the research.

## 2.2 The complex nature of Spatial Data Infrastructures

Many authors have already indicated that SDIs have a tendency to become complex (Chan & Williamson, 1999a; De Man, 2006a; Georgiadou et al., 2006). The first SDIs, called first generation SDIs (Rajabifard, 2003b), concentrated mainly on data storage, access and exchange. The complexity of those early SDI initiatives was mainly technological in nature. The second generation SDIs brought an increase in the numbers of users, applications and requirements. SDI functionality became more complex (Chan & Williamson, 1999a) as facilitating the interaction between data and people became a focal point of the SDI concept (Rajabifard et al., 2002). An SDI can therefore be seen as a sociotechnical assembly rather than simply a technical tool (De Man, 2006a). The variety of SDI actors and the intensity of interactions between them is one of the potential reasons for the complexity of such assemblies. As new SDI applications emerge the organizational structure grows and thus the number of people involved and the relations between them increase. As this progresses the initially complicated

SDI becomes rather complex. Moreover, complexity also arises as SDIs shift from being data-centric to service-centric infrastructures (Georgiadou et al., 2006). Following initial enthusiasm about the applicability of SDIs to help solve problems in a vast number of domains, it became clear that creating and managing SDIs is not easy. Even the large number of definitions of SDI illustrates the high level of disagreement among stakeholders about its nature.

It is important to discuss in more detail the role of the human factor in SDIs because people are probably the main reason for SDI complexity. The architecture of an SDI depends heavily on the nature of the environment in which it develops, especially the people who design, implement and work with it. Their experience, expertise, culture and objectives play a crucial role. Publications like the SDI Cookbook (Nebert, 2004) provide useful guidance, but in practice following the same recipe for building SDIs in different environments usually leads to different and often unexpected results. Moreover, in the course of time people may change the SDI concept. For example, one of the main rationales behind the transition from a product-based to a process-based model (Masser, 1999; Rajabifard et. al, 2002) was that SDI users and producers realized that the potential of SDI goes beyond simply managing data. The introduction of web services, increased data sharing between users and the shift in focus towards the use of data were the main drivers behind the evolution of SDI towards a process-based model (Crompvoets, 2006). Those changes and the evolution of SDI are only possible because people play a key role in the SDI concept. Referring to Rajabifard's et al., (2002) SDI conceptual model (see Figure 2.1) it has to be stressed that people are not limited to one side of the diagram as a separate component, but are rather an integral part of all other components, especially technology, policy and standards, and the human factor plays a key role in shaping those components: people develop the technology behind access network facilities; policies on SDI are solely created and obeyed by people; standards can only be developed and applied successful if people reach agreement. One of the key provisions of SDI is to improve spatial data sharing between individuals and organizations. Spatial data sharing depends mainly on social and cultural aspects because it requires agreements on common definitions and standards (Omran, 2007; Calkins & Weatherbe, 1995). SDI development requires an increase in a number of people to cope with the growth, but increasing the number of people results in an even faster increase of the number of possible communication channels (e.g. increasing the number of people from 2 to 4 increases the number of communication channels from 1 to

6). This effect might explain why human systems (including SDIs) become so difficult to manage as the number of stakeholders increases. For all these reasons, the human component of SDI is probably the main reason for its complex nature.

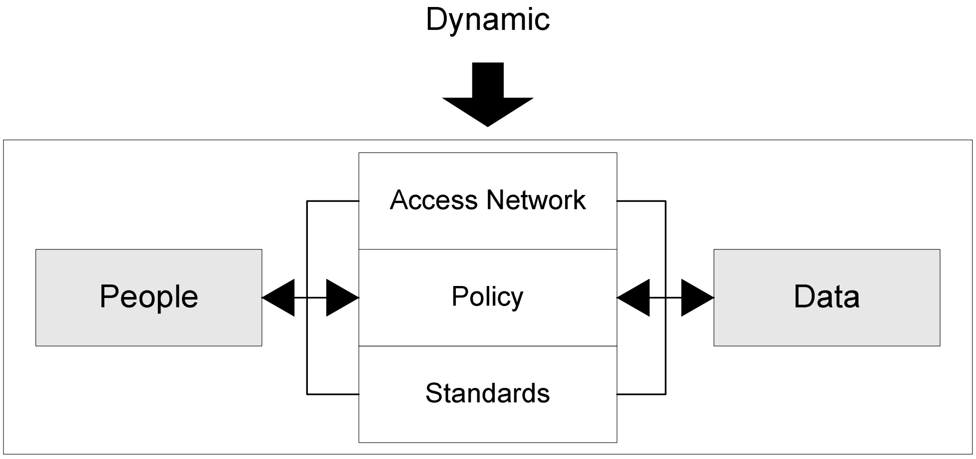


Figure 2.1 SDI components (source: Rajabifard et al., 2002)

The complex nature of SDIs is the reason for the difficulties encountered in trying to understand and assess them. The lack of knowledge on how to deal with the complexity of SDIs makes its assessment difficult. For example, it is difficult to attribute success or failure to one or more concrete factors. In other words, because SDIs are complex it is difficult to track cause-and-effect relationships (Rodriguez Pabón, 2005). Moreover, the dynamic and uncertain relations between the SDI building blocks – data, policies, standards, technologies and people – are hard to predict and control. In every part of the world, regional, national and local SDIs have a unique character and behave differently. This makes it difficult to implement SDIs in different environments in the same way and with the same outcomes. It has become clear that a proper understanding of SDI requires research that draws on knowledge from various fields, including technological, legal, economic, social and organizational domains.

Eoyang (1997) distinguishes two paradigms which can be used to analyse various phenomena: (1) Newtonian approaches and (2) complex approaches. The Newtonian approaches assume that the phenomenon is predictable, that certain procedures will lead to certain objectives, that the final outcome of the phenomenon performance is a sum of the performance of its parts, etc. In contrast, the complex approaches acknowledge uncertainties in a system due to emergent mechanisms in its functionality, the flexibility of system structures and adaptability to external conditions. They also acknowledge complexity rather than trying to simplify it. The choice of the approach depends on the characteristics of the phenomenon to be analysed (see Table 2.1).

Table 2.1 Newtonian versus complex approaches (adapted from Eoyang, 1997)

| **Use Newtonian approach when the problem is:** | **Use a complex approach when the problem is:** |
|---|---|
| Quiet familiar | New and unique |
| Well defined | Fuzzy or unknown |
| Closed to outside influences | Open to outside influences |
| Related to a small number of people you know well | Related to a large number you don't know well |
| One you've tried to solve before and succeeded | One you've tried to solve before and failed |
| Linear, the inputs and outputs are clearly distinguishable | Nonlinear, the inputs and outputs are not clearly distinguishable |

The choice of paradigm does not have to be mutually exclusive: Newtonian and complex approaches can also be used simultaneously. SDIs are quiet new (less than two decades of development), not well defined, not fully explored, changing, not solved and the outcomes are not well known. Therefore, the choice of the complex approach to analyse SDI is justified.

Understanding SDIs as CASs could help in identifying the mechanisms and forces that shape SDI development and in finding the best assessment strategy for SDI. The next section explains the concept of Complex Adaptive Systems in more detail.

## 2.3 Complex Adaptive Systems

Complex Adaptive Systems (CASs) have their roots in the study of chaotic systems (Gleick, 1989; Lorenz, 1993). Studies of various systems in different disciplines led researchers to focus on systems that moved from stable, predictable patterns into unstable, unpredictable behaviour (Kiefer, 2006). Results from further studies led researchers to identify two groups of chaotic systems: (1) unpredictable systems and (2) systems that moved through unpredictable states into new, more complex patterns of behaviour. The latter group has attracted attention from a wide group of researchers as Complex Adaptive Systems (Holland, 1998; Waldrop, 1992; Cilliers, 1998; Eoyang, 1996; Eoyang & Berkas, 1998). Intensive pioneering research on the concept of Complex Adaptive Systems was conducted at the independent Santa Fe Institute (SFI) for multidisciplinary collaboration. Many other scientists subsequently became interested in the concept of CAS and its applications, leading to the creation of many research groups at various scientific institutes all over the world devoted to complexity related research.[1]

Complex Adaptive Systems are defined in many different ways. For the purpose of this research we will use the following definition: 'CASs are open systems in which different elements interact dynamically to exchange information, self-organize and create many different feedback loops, relationships between causes and effects are nonlinear, and the systems as a whole have emergent properties that cannot be understood by reference to the component parts' (Barnes et al., 2003).

Complex Adaptive Systems have a specific number of features and behaviours that make them distinctive from other types of systems. The features are the set of system characteristics that together make CASs different from other systems. Similarly, CAS behaviours are the distinctive collection of system activities and processes that make CAS behaviour unique. The collection of CAS features and behaviours used in this research is based on many resources on complex systems (Cilliers, 1998, 2005; Eoyang, 1996; Eoyang & Berkas, 1998; Barnes et al., 2003; Rotmans, 2005; Walldrop, 1992). Because the CAS literature we reviewed contained variations and differences in the number and names of the CAS features and behaviours, for the purpose of this research we limited the list to those CAS features and behaviours that were common to the literature sources reviewed.

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[1] The main resaearch institutes dedicated to this research are: Santa Fe Institute (http://www.santafe.edu); University of Michigan Center for the Study of Complex Systems (CSCS) (http://www.cscs.umich.edu/); Northwestern Institute on Complex Systems (NICO) (http://www.northwestern.edu/nico/); Max-Planck Institute for Physics of Complex Systems (http://www.mpipks-dresden.mpg.de/); Center for Complex Systems Research (http://www.ccsr.uiuc.edu/); New England Complex Systems Institute (NECSI) (http://www.necsi.org/); Center for Complex Systems (OBUZ) - ISS Warsaw University (http://www.iss.uw.edu.pl/osrodki/obuz/OBUZNEW_ENG/obuz.htm); Banding Fe Institute Official Web (http://www.bandungfe.net/)

CAS features:

Components – CASs always consists of relatively stable and simple building blocks (Cilliers, 2005) that are linked via mutual interactions (Rotmans, 2005; Eoyang & Berkas, 1998). Holland (1998) states that building blocks are a pervasive feature of complex adaptive systems.

Complexity – The system's behaviour emerges because many of the simple components interact simultaneously (Walldrop, 1992; Cillers, 2005). In principle, this means that there is a constant exchange of information and needs between the components and actors in the system. Complexity also means that the whole of the system is different from the sum of its parts (Eoyang, 2004); complex systems cannot be analysed only by examining their parts separately.

Sensitivity to initial conditions – In CASs a small initial action may have a major effect in the future. Very small difference in the initial state of the system may result in a big change in the outcome. For example, changes to a single legal document may have a major effect on many organizations, or even on society as a whole.

Openness – CASs interact with their environment (Rotmans, 2005) and are susceptible to external influences (Eoyang & Berkas, 1998). It is also difficult to define clearly where the boundaries of complex and adaptive systems are (Barnes et al., 2003).

Unpredictability – It is hard to be sure about the final outcome of the system's behaviour. The unpredictability of CASs is a result of many actors taking independent actions that subsequently influence other actors and their actions. To make sense of the output of the complex system we must take into account the mechanisms by which it is produced (Cilliers, 1998). However, predictions can never be made with certainty.

Scale independence – Different hierarchical levels of CASs have a similar structure (the 'fractal building'). This feature can be found in organizations where the same characteristics (e.g. functional dependencies, relations between employees, policies and rules) can be seen from the bottom to the top of the management chain (Eoyang & Berkas, 1998).

CAS behaviours:

Adaptability – As part of the wider environment, CASs are able to adjust and adapt themselves to external influences (Cilliers, 2005; Rotmans, 2005). For example, increasing concurrence in the sector may force a particular company or organization to adapt by changing its organizational model to a more efficient one. However, system adaptability may also be a result of internal factors, like the operation of a system's memory: the system may change as it learns from its own experience. According to Holland (1998), adaptation can also be described as a change in the system's structure (strategy) resulting from the system's experience.

Self-organization – The ability of CASs to develop a new system structure by themselves is a result of their internal constitution and not a result of external management (Rotmans, 2005). According to Eoyang (1996) a system self-organizes if it is pushed far enough away from its equilibrium state. Examples of self-organization in human systems are spontaneous group activities, like revolts. Cilliers (1998) defines self-organization as a process in which a system can develop a complex structure from fairly unstructured beginnings. The process occurs under the influence of both the external environment and the history (memory) of the system.

Nonlinear behaviour – In CASs it is difficult to determine the value of a second variable, even when a first variable is known (Eoyang, 1996). Changes are prompted by external or internal factors boosting or slowing the system down. Cillers (2005) explains this nonlinearity by describing interactions as dynamic input-output relations. This means that the strength of interaction changes over time. For example, changes in political strategies may have a causal influence on CAS behaviour or development.

Feedback loop mechanism – The system has a tendency to use its own output to adjust its inputs and processes (Eoyang, 1996). Two types of feedback loops can adjust the behaviour of complex adaptive system: negative and positive. The evaluation process is an example of a feedback loop, which may be either positive or negative. It is positive when the system learns from the evaluation and enhances its performance and negative when negative evaluation results discourage programme participants. If designed properly, positive feedback mechanisms facilitate change and adaptation of the system (Patton, 1990).

## 2.4 Methodology

To determine whether SDIs can be viewed as CASs, we followed three research steps.

First, the common features and behaviours of most Complex Adaptive Systems were identified. The CAS features and behaviours presented in section 3 were selected in two steps: (1) from the rigorous review of CAS literature we collected all CAS features and behaviours; (2) we reduced the number of features and behaviours to those that were common to all CAS literature.

Second, we followed a case study research method to empirically identify CAS features in three national SDIs. The pattern-matching technique (Yin, 2003) was used to analyse the case study evidence. The technique was applied in the following way. A hypothesis stating that an SDI is a CAS was made. The hypothesis assumes that certain CAS features and behaviours (patterns) are present in SDI cases (see section 5). These hypothetical patterns were then compared with the empirical evidence from the case study analysis and summarized in a table (see Table 2.3). If there was strong evidence for a pattern match, we assigned an 'in agreement' label. For weaker evidence we assigned a 'neutral' label. Where the case study analysis revealed a different pattern than the one suggested by the hypothesis, we assigned a 'not in agreement' label. In some cases we could not find any information on CAS features and behaviours in the SDI case studies. In those cases we assigned a 'no information' label.

The rationale for using the case study method for this research was based on four conditions for selecting case study as a useful strategy for conducting research (Pare, 2004): (1) the phenomenon is complex; (2) the existing body of knowledge does not allow us to pose causal questions; (3) holistic and in-depth investigation is needed; (4) the phenomenon cannot be studied outside its context. At least the first three conditions are valid for SDIs as they are complex and the mechanisms behind them are not fully understood, which makes it difficult to pose causal questions. Moreover an in-depth investigation of the whole SDI is needed to be able to identify CAS features and behaviours. Case studies of three national SDIs (NSDIs) – from Australia, the Netherlands and

Poland – were chosen for practical reasons. The case study approach requires in-depth analysis of the documents, which usually are written in the national language and all of them could be accessed and understood by the authors of this study. Additionally, the three cases represent three different approaches to setting up and operating SDIs: very hierarchical (Poland), voluntary (the Netherlands) and a mix of the two (Australia). Each NSDI case description was reviewed by a key SDI contact person for that country to confirm the validity of the facts. These key people are actively involved in the development and coordination of the NSDI in their country.

Third, an anonymous internet-based survey was carried out. The survey was sent to 33 participants of the 'Multi-view framework to assess National Spatial Data Infrastructures' workshop held at Wageningen University in 2007 (Crompvoets & Grus, 2007). The workshop main topic was the SDI assessment. It also included one presentation in which the potential relationship between SDI and CAS was mentioned. As a survey population 33 participants were selected out of a total of 45 participants because they attended the workshop the full three days and as a result they received a similar amount of information. All workshop participants were professionally closely related to SDI. Table 2.2 describes the characteristics of the survey population.

Table 2.2 Characteristics of survey population

| Country | Number | Sector | Number | Role | Number |
|---|---|---|---|---|---|
| Australia | 2 | Government | 12 | Scientists | 20 |
| Belgium | 3 | Academia | 18 | Policymakers | 8 |
| Canada | 3 | Private Sector | 3 | Data and/or Software Producers | 5 |
| Cuba | 2 | | | | |
| Greece | 1 | | | | |
| Italy | 2 | | | | |
| Netherlands | 14 | | | | |
| Nepal | 1 | | | | |
| UK | 1 | | | | |
| USA | 4 | | | | |

The workshop participants were asked to express their strength of support for 21 statements about the presence of 6 CAS features and 4 behaviours in SDI. The statements were formulated in such a way that the survey respondents could agree or disagree with them using the following scale: strongly agree, agree, neutral, disagree, and strongly disagree. Each CAS feature or behaviour was described in its SDI context by two statements. In addition, the workshop participants were asked whether a SDI can also be described as a 'system', the definition of which was adapted from the Longman Dictionary of Contemporary English (1995). The questionnaire focused on the overall concept of SDI and did not specify any particular SDI levels, such as national, local or regional. The internet-based survey was performed 10 months after the workshop. The survey objective, which was to check CAS features and behaviours in SDI context, were not mentioned to the respondents. The survey questions were also formulated in neutral way asking respondents about their opinion about some SDI characteristics so they could not know that the questions were about to check SDI and CAS similarity. Therefore, we assume that the respondents were not biased by the past workshop. The questionnaire and respondents' answers can be found in Appendix 1.

## 2.5 Hypothesis

The hypothesis that we tested is: 'Spatial Data Infrastructure can be viewed as a Complex Adaptive System'. The truth of the hypothesis is highly probable if CAS features and behaviours can also be identified in SDIs. Based on the proposed hypothesis, the following features and behaviours, similar to those found in CASs, are also expected to be present in SDI:

- SDI consists of a number of identifiable components.
- SDI is a complex phenomenon because it consists of many components and multiple actors which constantly interact with each other.
- SDI is sensitive to initial conditions, i.e. decisions made about SDI at the initial stage of its development may have an impact on its future development.
- SDI is open because it interacts with (i.e. adapts to, has influence on, learns from) other sectors. SDI is also open as it is very difficult to define its boundaries.
- SDI is unpredictable because we cannot be sure how it will look and how it will function in the future.
- SDI architecture is self-similar on different levels of the hierarchy. For example, in both local and national SDIs it is possible to identify similar

building blocks (data, policies, standards, etc.). Each building block also has a similar function either in local, regional or national SDIs.

- SDI is able to adapt its own structure and functions to new user or market requirements and demands. It is also able to incorporate new technologies that emerge in other sectors and might be beneficial for SDI.
- SDI is able to self-organize (or self-regulate) which is the result of communication, interaction and learning from past actions. Bottom-up activities and initiatives to improve SDI (e.g. the rapid response of the SDI community to emerging user needs and requirements) might indicate the self-organizing ability.
- SDI behaviour is nonlinear in such a way that its development may be disturbed by internal and external factors (e.g. a lack of political support for SDI may slow down its development or push it in a different direction). As a result, the intended SDI objectives might not be met.
- SDI has feedback loop mechanisms which enable it to learn from its own experience. For example, stakeholders may use performance or output assessments to refine their actions towards developing SDIs. Evaluation, innovation and scientific programmes embedded in SDIs that emerge during its development might indicate the existence of feedback mechanisms.

## 2.6 Results

This section presents the research results. Section 6.1 presents the results of the case studies analysis. Each case analysis starts with a description of the SDI case, followed by a short description of each CAS feature and behaviour in the context of the SDI. Section 6.2 presents the results of the survey on similarities between CAS and SDI.

### 2.6.1 Case studies

*2.6.1.1 The Australian NSDI as CAS*

The facts about the Australian SDI are mainly based on Clarke et al. (2003), Chan et al. (2005), Warnest et al. (2005), Department of Industry, Tourism and Resources (DITR) (2004) and Blake (2005).

The beginnings of Australian SDIs lie with the Australasian Urban and Regional Information Systems Association - AURISA (presently part of Spatial Sciences Institute - SSI). In the late 1970s and 1980s AURISA was a major catalyst for bringing together state agencies to discuss land information systems. Those efforts energized other states, local governments and finally the national government. In 1986, by agreement between the prime minister and the heads of the Australian state and territory governments, an Australian Land Information Committee was established. In 1991 it became the Australian and New Zealand Land Information Committee (ANZLIC) and since 2004 it has been known as ANZLIC – The Spatial Information Council. Its formation was a response to the growing need to coordinate the collection, transfer and promotion of land-related information. ANZLIC's role is to establish policies, standards and guidelines to facilitate access to spatial data and services provided by many organizations dispersed across the country. ANZLIC coordinates the development of the Australian SDI (ASDI) through its vision that recognizes that Australia's spatially referenced data, products and services should be widely available and accessible to users. The Australian and New Zealand governments are each responsible for coordinating spatial information policies in their jurisdictions; ANZLIC encourages the coordination of activities which are of national importance via ANZLIC representatives that reside in each jurisdiction. At the national level, GeoSciences Australia is a Commonwealth government agency that collects and maintains small-scale mapping and spatial datasets. Several other bodies have emerged in the recent years, strengthening the public, private, professional and research SDI dimensions. At the national level the key ASDI players are:

- ANZLIC, an intergovernmental SDI coordinating agency;
- Public Sector Mapping Agency (PSMA), a public company that integrates critical spatial data from governmental sources (national and from each jurisdiction) to support spatial data users. PSMA plays an important role in ASDI because it builds national spatial data from Commonwealth or

state/territory data and utilizes them via the network of value adders. PSMA's chair is also a member of ANZLIC;

- Australian Spatial Information Business Association (ASIBA), a professional association that aims to represent industry's spatial information needs and interests;
- Spatial Sciences Institute (SSI), a national body providing a forum for professional people in the spatial information industry in Australia. In the near future it will be named Surveying and Spatial Sciences Institute;
- Centre for SDI and Land Administration at the University of Melbourne, research centre established in 2001 within the Department of Geomatics. Its research focuses on designing and developing SDI, spatially enabling government and society, cadastral system, land management, etc.
- Cooperative Research Centre for Spatial Information (CRC-SI), which undertakes spatial information-related research in location, image analysis, spatial information systems, remote sensing, etc.;
- The Australian Spatial Consortium (ASC), a consortium supported by CRC-SI whose objective is to unlock and utilize the potential of spatial information within the industry

The Australian SDI framework comprising the aforementioned players operates through consensus. The Commonwealth has not adopted any legal requirements or pressured the actors within the ASDI in any way.

*Components*

ANZLIC's definition of ASDI recognizes people, policies and technologies as SDI components. According to this definition, these components are necessary to enable the use of spatially referenced data at all levels of government, the private and non-profit sectors and academia.

*Complexity*

The complexity of ASDI arises from the requirement for cooperation between the national government and nine state governments. Moreover, the large number and diversity of players who constitute and contribute to ASDI often have different needs, but have to interact and cooperate with each other. This makes the situation even more complex. This complexity, however, is managed by an organizational structure coordinated by ANZLIC.

*Sensitivity to initial conditions*

The Australian state agencies for spatial data focused quiet naturally on high resolution data covering their state territory. Because of AURISA's initial activities in bringing together those state agencies to create ASDI (see case description), the present ASDI can be characterized by relatively strong role of state SDIs and easy availability of high resolution datasets.

*Openness*

The creation of the Australian Spatial Consortium (ASC – see case description) to make use of the potential of spatial information in other industrial domains suggests that ASDI is open to interaction with other sectors. Also, the existence of ASIBA, which represents the interests of industry in spatial information, is some evidence that ASDI reaches out beyond its own organizational boundaries and that SDI applications can serve the real needs of industry. ASDI is also open to its international environment through the active membership of ANZLIC in the Permanent Committee on GIS Infrastructure for Asia and the Pacific (PCGIAP), a regional SDI initiative.

*Unpredictability*

ANZLIC's strategic plan and work programme is defined until 2010. It is still unknown what will happen after this date, whether all the intended outcomes have been achieved or not. The future of ASDI after 2010 cannot therefore be predicted with much certainty. However, the relatively widespread recognition of SDI benefits and the existence of many independent bodies playing different roles in the ASDI suggest that its existence is not in any real danger in the near future. This strong acceptance of the SDI concept in Australia reduces its unpredictability.

*Scale independence*

Australian SDI can be characterized by a clear division between national and state or territory SDIs. Replication of the SDI model from the higher ASDI level (ANZLIC) to lower state levels (represented by the Australian Capital Territory Planning and Land Authority, the New South Wales Department of Lands, the Northern Territory Department of Planning and Infrastructure and others) is evidence of the scale independence of ASDI. In other words, similar organizational structures and roles are present on all ASDI levels (from local, through state to federal). Such hierarchical capability for SDI helps to exploit the main benefits of the concept because SDI challenges faced at the national level (e.g. standards implementation, data access policy, data sharing models) may be similar to those at state or territory levels.

*Adaptability*
Initially ANZLIC focused mainly on land administration (cadastral) systems. Later, as the general SDI concept was maturing, Australian SDI recognized the much broader potential of the ASDI and changed its goals and objectives. It adapted to broader market requirements by changing the scope of its activities from narrower 'land-related information' to broader 'spatial information'.

*Self-organization*
The heterogeneity of players in the ASDI and its openness to external factors facilitates the flow of information and energy and thus allows the system to self-organize. ANZLIC was established in response to the need to coordinate the provision of land information and the ASDI framework was developed as a distributed system in which multiple state/territory agencies operate their own SDIs. The Commonwealth does not have any legal powers to force other players to comply with national policies or standards. Given that the ASDI has been created mainly through consensus and in a very distributed environment, its capacity for self-organization is rather high. Moreover, the recognition of the geographical information sector's needs and the emergence of new bodies from within the 'spatial community' in recent years indicates that the ASDI has a high self-organizing potential.

*Nonlinear behaviour*
No information that matches this CAS behaviour has been found.

*Feedback loop mechanism*
Each year ANZLIC reports on its performance in coordinating and implementing the ASDI. These activities form a kind of formalized feedback mechanism that is an integral part of ANZLIC's activities. Moreover, activities like those of CRC-SI (Cooperative Research Centre for Spatial Information), which recognized the need to carry out the Spatial Information Action Agenda as a critical step in

developing ASDI, can be regarded as a feedback loop mechanism. This feedback mechanism boosted the development of the ASDI by supporting and enhancing national research priorities related to spatial sciences. Another example of a feedback loop mechanism was ANZLIC's decision to audit the Australian Spatial Data Directory (ASDD) to check the quality of the metadata. This audit resulted in a number of recommendations for improving the quality of the ASDI.

#### *2.6.1.2 The Dutch NSDI as CAS*

The facts about the Dutch SDI are mainly based on Bregt (2000), Bregt and Meerkerk (2007), Spatial Application Division Leuven (SADL) (2006), Ravi (2003), Van Loenen and Kok (2002), Van Loenen (2006) and Ministry of Housing, Spatial Planning and the Environment (VROM) (2008).

The development of the Dutch NSDI dates back to 1990 when Ravi, a network organization for geo-information, was established. Initially, Ravi was an official advisory committee on land information at the Ministry of Housing, Spatial Planning and the Environment (VROM). In 1993 it became an independent consultative body for geo-information, its members being representatives from various public sector bodies. In 2007 Ravi and the National Clearinghouse for Geo-Information (NCGI) merged to form Geonovum. Geonovum is acting on an operational level of Dutch SDI organization. It is the NSDI executive committee in the Netherlands with the task of coordinating the development of the NSDI and providing better access to geo-information in the public sector. On strategic level GI-council, established in 2006, advises the Ministry VROM on strategic actions relating to geo-information sector.

The development of the Dutch NSDI can be described as a combination of many bottom-up initiatives, with some form of central coordination. For example, the ministry of VROM has taken on the role of formal geo-coordinator. However, the NSDI initiative has always been left to develop through a process of self-regulation by the geographical information (GI) sector, which has no formal powers to compel public agencies to participate in the Dutch NSDI. In 1992 Ravi presented a structure plan for land information that soon turned out to be a vision for the Dutch NSDI. The idea was to draw up agreements between authorities to facilitate the exchange of core registers. By the end of 2002 the objectives of the vision had almost been achieved. The next stage in the development of the Dutch NSDI is described in a new vision document called GIDEON (VROM, 2008), which is adopted by the Dutch Government.

*Components*

The components of the Dutch NSDI are recognized in the definition of the NSDI: The National Geographic Information Infrastructure (NGII) is a collection of policy, datasets, standards, technology (hardware, software and electronic communication) and knowledge, providing the user with the geographic information needed to carry out a task.

*Complexity*

In 2002, the Dutch Council of Ministries agreed to invest 20 million euros in the 'Space for Geo-Information' innovation programme (Ruimte voor Geo-Informatie, RGI) to improve the current geo-information infrastructure and stimulate the necessary innovation for the future. The number of partners involved in the programme related to the GI sector and SDI development is about 200. Additionally, the GIDEON vision document was drawn up through the cooperation and commitment of 21 SDI-related organizations. The high number and diversity of Dutch GI players and the coordination of their actions make the Dutch GI community very complex.

*Sensitivity to initial conditions*

Ravi was initially an advisory body of the ministry of VROM. This initial close connection to the ministry might be the reason why governmental bodies continue to give strong support the GI initiatives and still recognize its importance, which has allowed the GI sector to develop more easily. Despite the reorganization of the SDI coordinating bodies (e.g. from Ravi to Geonovum), the people that were initially involved in the creation of the Dutch NSDI at the beginning of 1990s are still involved and the model of cooperation that stresses the importance of bottom-up initiatives and voluntary actions still persists today.

*Openness*

The openness of the Dutch NSDI is expressed in its cooperation with a wide range of parties. Ravi (now Geonovum) even found supporters of the vision outside the geo-information sector, especially in the Ministry of the Interior. The Dutch NSDI is also open to regional SDI initiatives like the EU INSPIRE Directive and cross-border projects with Germany. The mission of the Dutch knowledge project 'Space for Geo-Information' is to create 'a geo-information network that will be more dynamic and open' within the next ten years. This means that the network has to be flexibly integrated with adjacent disciplines, has to exchange knowledge and has to cooperate with them.

*Unpredictability*

The unpredictability of the NGII is exemplified by the knowledge project 'Space for Geo-Information', which is based on the premise that there is no sense in looking at GI development beyond a ten-year time horizon because of its short history and probable unpredictability. However, there are currently activities underway with the aim of continuing the 'Space for Geo-Information' initiative after the initial ten-year period. Moreover, the great number of SDI-related activities in both the public sector and the private sector provide sufficient grounds to be confident that the Dutch NSDI will continue in future.

*Scale independence*

Local or institutional SDIs usually comprise the same components as those listed in the definition of the Dutch NGII. For example, Geodesk, an SDI created by the research institute Alterra, has the same components (data access facility, standardisation and policy) and has the same functions (improving access to data and data sharing) as those defined for the NSDI. However, because its highly decentralized structure makes it hard to identify hierarchical levels in the Dutch NSDI, we cannot conclude that the scale-independence feature is present at various hierarchical SDI levels.

*Adaptability*

An example of the adaptability of the Dutch NSDI is the introduction by Geonovum of a new prototype of the Clearinghouse that provides access to the Dutch Web Mapping Service, which complies with OGC standards. It is already the fourth version of the Dutch Clearinghouse. Each version embraces emerging new IT technologies that can be used in SDI clearinghouse implementations. Moreover, the concept behind the clearinghouse is adapted with each new version – from being a central (meta)data repository to a network of data providers. The possibility of displaying some of the available date layers in Google Earth exemplifies how the clearinghouse capabilities are being adapted to the emerging new technologies (i.e. Google Earth) in the GI sector.

*Self-organization*

According to Masser (2005a), the Dutch NSDI falls into the category of NSDIs that have grown out of existing geographical information coordination activities. Bottom-up processes play a crucial role in its development. For example, the new SDI policy document GIDEON, which sets out a vision, strategy and implementation plan for the Dutch NSDI, was initiated and created by the main SDI stakeholders and commented on by the relevant government departments and governmental bodies. The Dutch NSDI development model can therefore be described as a voluntary rather than mandatory. Ravi (since 2007 Geonovum) has no legal powers, but this does not discourage the stakeholders from basing their SDI development activities around it. We may conclude, therefore, that the success of the NGII in the Netherlands lies in the strong self-organizing ability of the GI community.

*Nonlinear behaviour*

The nonlinearity of the development of the Dutch NSDI is only visible in some of its aspects. Emerging new technologies were one of the reasons for the relatively unstable development of the Dutch Clearinghouse (for example, the failure of the National Clearinghouse for Geo-Information). However, the pursuit of the objectives of the first NSDI strategy went according to plan. It was therefore relatively linear.

*Feedback loop mechanism*

The 'Space for Geo-Information' innovation programme can be regarded as an outcome of a feedback mechanism within the Dutch NSDI. Following the successful execution of the first NSDI vision, the NSDI community and the government recognized the need for further research and the development and the creation of a new vision for the Dutch GI sector. This resulted in the investment of 20 million euros over a period of ten years to improve the performance and stimulate the further development of the GI sector.

*2.6.1.3 The Polish NSDI as CAS*

The facts about the Polish NSDI have been drawn mainly from IGiK (2001) and SADL (2007).

The Polish NSDI has been under development for many years, but its status and structure are still unclear. The first SDI-like initiatives started in the 1970s, when the National Land Information System was first put into effect.

During the 1980s the system changed and adapted to the conditions of the market and the economy (Gazdzicki & Linsenbarth, 2004). These initiatives came to an end due to the many organizational, administrative and political changes over the following two decades, but now the Polish NSDI initiative is emerging again. Under the Geodetic and Cartographic Law, coordination of the NSDI in Poland was entrusted (however not in a straightforward way) to the Surveyor General of Poland, the director of the Head Office of Geodesy and Cartography (GUGiK). Most of the other bodies participating in the Polish NSDI are representative bodies for geodetic and cartographic services (the Association of Polish Surveyors, the Association of Polish Cartographers, the Institute of Geodesy and Cartography, the Polish Spatial Information Association and the National Association of GI Systems Users GISPOL). The coordination activities are funded by the Ministry of Infrastructure. The National Land Information System Decree defines the scope and content of the NSDI and bodies responsible its the establishment and management. The NSDI is defined by the Geodetic and Cartographic Law as a database, procedures and techniques for collecting, updating and disseminating spatial data. It consists of two types of components: core components (reference datasets), managed by the Surveyor General, and thematic components, managed by various ministries. The current status of the Polish NSDI can be characterized as a patchwork of more that 100 spatial information systems at different administrative levels across the country. One of the objectives of the NSDI should be the integration of those initiatives, but the degree of coordination is not clear. Between 1998 and 2000 a research project titled 'The Concept of the Polish Spatial Information System' was commissioned by the Ministry of the Interior and Administration. Its goal was to propose a general concept for the NSDI in Poland. So far progress with putting the postulates of this research into effect has been limited and marginal.

*Components*

The Geodetic and Cartographic Law defines the NSDI as a spatial data database and techniques and procedures for the systematic collection, updating and dissemination of datasets. To some extent these three defined building blocks – database, techniques and procedures – can be regarded as components of the Polish NSDI.

*Complexity*

The dynamic and heavily entwined relationships, and especially the different and often contradicting interests of many of the key NSDI players and institutions, are evidence of the complexity of the Polish NSDI. Besides, the task of coordinating 100 spatial information systems dispersed across the country is complex enough without these additional complications.

*Sensitivity to initial conditions*

Sensitivity to initial conditions has been apparent in the Polish NSDI since its beginnings. Pre-NSDI initiatives had always taken place mainly within the geodetic domain and the geodetic community still has the strongest influence on the Polish SDI scene.

*Openness*

The knowledge and experience of the geodetic community and related organizations cannot be questioned. However, their dominance in activities for the creation of the NSDI in Poland can hinder its openness to cooperation with other domains and other non-geodetic players. For example, one of the objectives of the GISPOL association of GI users, which has its roots in geodesy, is to 'oppose the diffusion of geodetic datasets' or to 'give preference to the supporters of its actions'. This raises questions about the openness of geodetic bodies, and thus the NSDI, to other players from other domains.

*Unpredictability*

When we look back and analyse the very dynamic and promising pre-NSDI initiatives of the 1970s (the concept of Information System TEREN), the 1980s (Multipurpose Cadaster initiative) and current initiatives, it can be concluded that the development of the NSDI in Poland is very unpredictable. Most of the initiatives were suspended or not successful due to external factors like political system change or administrative reform.

*Scale independence*

No information that matches this CAS characteristic has been found.

*Adaptability*

The difficulty with adaptation is shown by the limited compliance of the Polish NSDI with the EU's INSPIRE Directive, despite the establishment of the Rada Implementacyjna Inspire (Inspire Implementation Committee) in 2007.

*Self-organization*

The semi-formal mandate given to the Surveyor General, as the head of GUGiK, to coordinate the operation of the Polish NSDI may be some evidence of the self-organization ability of the system. However by designating to GUGiK coordination of Polish SDI tasks, geodetic organizations got relative advantage in building SDI. The attempts to formalize the creation of the NSDI by geodetic bodies leave little room for initiatives by other GI players and thus limit the self-organization mechanisms. As a result, the main Polish NSDI players are concentrated around the well-established and influential geodesy community without much opportunity for bottom-up approaches.

*Nonlinear behaviour*

The history of Polish SDI development is characterized by the emergence of many initiatives, which for a number of reasons collapsed (see also the paragraph on Unpredictability above). This is evidence of very nonlinear behaviour in the Polish NSDI.

*Feedback loop mechanism*

The research project 'The concept of the Polish Spatial Information System' may be an example of a positive feedback loop. After a number of attempts to create an NSDI, the Ministry of Interior and Administration reflected on the lessons learned and ordered a research project with the aim of formulating a comprehensive concept for the Polish NSDI. However, due to formal and organizational constraints (no formal mechanism to carry out the postulates from the concept) the concept has not yet been implemented. Table 2.3 summarizes the results of the case study analysis. The detailed discussion of these results can be found in section 7.

Table 2.3 Summary of CAS features and behaviours for each case study country

| CAS features and behaviours | Australia | The Netherlands | Poland |
|---|---|---|---|
| **CAS features in SDIs** | | | |
| **Components** | In agreement | In agreement | Neutral |
| **Complexity** | In agreement | In agreement | In agreement |
| **Sensitivity to initial conditions** | In agreement | In agreement | In agreement |
| **Openness** | In agreement | In agreement | Not in agreement |
| **Unpredictability** | Not in agreement | Not in agreement | In agreement |
| **Scale independence** | In agreement | Neutral | No information |
| **CAS behaviours in SDIs** | | | |
| **Adaptability** | In agreement | In agreement | Neutral |
| **Self-organization** | In agreement | In agreement | Not in agreement |
| **Nonlinearity** | No Information | Not in agreement | In agreement |
| **Feedback loop** | In agreement | In agreement | Neutral |

### 2.6.2 Results of the SDI as CAS questionnaire

The intention of the questionnaire was to explore the truth of the hypothesis that Spatial Data Infrastructures can be considered to be Complex Adaptive Systems by asking for the opinion of SDI experts. From the 33 questionnaires sent, we received 27 answers (an 82% response rate). Figure 2.2 presents a summary of the results of the questionnaire. Detailed results of the questionnaire can be found in Appendix 1. Each bar in Figure 2.2 represents the level of support for the existence of CAS features and behaviours. The percentages were obtained by summing Strongly Agree (SA) and Agree (A) or Strongly Disagree (SD) and Disagree (D) responses (depending on the statement formulation) for each statement relating to a CAS feature or behaviour. The results show that the level of support for all CAS features and behaviours was more than 50%. The respondents to the questionnaire expressed the highest support for the statements that SDIs are open (96% and 78%). Statements about the sensitivity to initial conditions and the unpredictability of SDIs also received relatively high support (89% and 78%, and 93% and 70% respectively). The self-organizing behaviour of SDIs was supported by 56% of the respondents in the first statement and by 89% in the second statement, which was the biggest difference in the level of support between statements 1 and 2. The existence of a feedback loop mechanism was supported in two statements by 70% and 74% of the respondents. The respondents expressed the lowest support to the statements suggesting that SDI is adaptable: 52% and 59%.

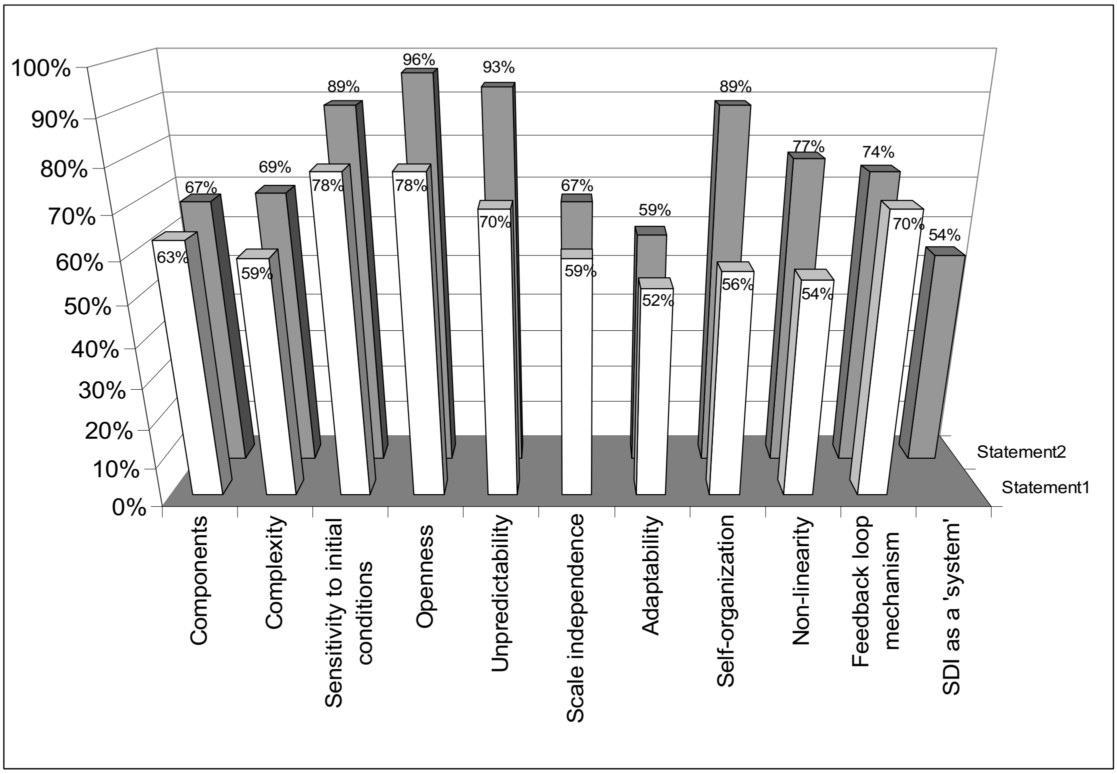


Figure 2.2 SDI as CAS questionnaire results: level of support for each CAS feature and behaviour expressed as a percentage

## 2.7 Discussion

The objective of the research was to determine whether or not Spatial Data Infrastructures can be viewed as Complex Adaptive Systems. To meet this objective we used two methods: (1) analysing three case studies of NSDIs, (2) conducting a survey on complex characteristics and features that could be found in SDIs. Here we discuss the results of using these two methods in our research.

Most of the CAS features and behaviours (with two exceptions where no information has been found – see Table 2.3) were identified in all three NSDI cases. In the Dutch and Australian SDI case studies it was possible to identify similar CAS behaviours and features to those stated in the research hypothesis. However, in both cases the unpredictability feature could not be matched with the pattern typical for CAS. The possible reason for this might be that SDIs are rather unpredictable only in their early stages. In the course of time, as the SDI concept matures and its benefits and necessity are well recognized, the continued existence of the SDI becomes more certain. This change may also occur for other CAS features and behaviours. In the Polish NSDI, which is still in its infancy compared with the Australian and Dutch NSDIs, some CAS features and behaviours are different from those in the two other NSDI cases. For example, the Polish NSDI is evidently less open and less self-organizing. This might be typical for early stages of SDI development, in which the SDI community concentrates only on its own development and therefore is rather closed.

The result of the questionnaire show that the majority of workshop participants agree that SDIs are similar to and behave like CASs. More than half of the workshop participants agreed that all of the CAS features and behaviours can be identified in SDIs, giving the highest support to openness, unpredictable behaviour and sensitivity to initial conditions. It is important to note that the smallest number of workshop participants agreed with the adaptive behaviour of SDI and a third of the respondents were neutral on these statements (see detailed data in Appendix 1). This could mean that the respondents do not reject the fact that SDIs are adaptable, but are not thoroughly convinced. The reasons for the large difference between the levels of support for the two statements about the self-organizing behaviour of SDI (33%) could be that one of the statements is wrongly formulated or was not clear to the respondents (see statements 7 and 21 in Appendix 1). This could also explain the inconsistency between the respondents' answers to the statements about nonlinearity and unpredictability. For both characteristics, the difference between the level of support for the first and second statements is 23%. The level of support for the remaining pairs of statements is quite consistent: the differences between the support for statements 1 and 2 vary from 4% to 18%.

The two methods that were used in this study – case study analysis and questionnaire survey – complement each other. The case studies concentrated specifically on NSDI implementations and data that were collected only from written documentation, whereas the questionnaire focused on the general SDI concept and data were collected by means of an online form filled in by SDI experts. The results of the online questionnaire confirm the findings of the case study analysis.

We must also discuss the limitations of the research methods that we used. In the case study analysis, data were collected from official documents and publications. For practical reasons not all official documents on each country's NSDI are publicly available and not available to us also. Therefore we must assume that the picture we tried to draw on each NSDI might be not complete. Additionally, because the documents about each NSDI were read and interpreted by the authors of this study, the case study analysis may involve some level of subjectivity. To minimize these limitations we asked SDI experts from each country to review the text of each NSDI case and confirm the truth of the facts. The main limitation of conducting an online questionnaire survey is the possibility that the respondent misinterprets or does not properly understand the questions. In an attempt to reduce this risk, the respondents were given the opportunity to comment on each statement to allow us to identify any misinterpretations and take any comments on the nature of the statement into account.

The mix of respondents to the questionnaire suggests there may be a certain bias in the results (see Table 2.2). The number of respondents from the Netherlands is higher than from other countries. Moreover, the proportion of scientists in the group of respondents is high and the number of respondents from the private sector is much lower than from government and academia. Nevertheless, the survey questions were relatively abstract and not related to any sectoral domain (i.e. private, public or academic) and not related to any territory. As the aim of the questionnaire was to gauge the respondent's mental attitude to the questions that we asked, we assumed that the respondents' country of origin and role they play would have a limited impact on the answers.

The research results suggest that although SDIs do not resemble CASs in every aspect, they can certainly be treated and analysed as CASs. Viewing SDI through the lens of Complex Adaptive System theory allows us to better explain and understand SDI. It is clear that features and behaviours like openness, level of self-organization, adaptability, existence of feedback loop mechanisms, etc. play an important role in the efficient and effective functioning of SDI. SDI should be able to self-organize and be open in order to create its own structure and to cooperate with other domains. However, without any coordinating mechanism it is difficult to successfully establish and manage an SDI. The importance of any kind of positive feedback loop mechanisms (i.e. activities that evaluate past SDI activities and set goals for its future development) cannot be underestimated. Self-organization, openness and feedback loop mechanisms provide SDI with the capacity to adapt to changes. A high degree of adaptability guarantees that an SDI can continuously develop by adjusting its structure, behaviour and goals to changing external circumstances. It is also evident that although unpredictable and nonlinear behaviour cannot be eliminated, in a well operating SDI these characteristics can be minimised by a well functioning coordination body and by building long-lasting societal and governmental awareness of the necessity of having and maintaining an NSDI. Defining SDI components clearly helps to systemize and manage its complex structure. Being aware of the fact that SDIs are sensitive to initial conditions might help in identifying the small factors that play an important role in shaping SDI structure. Awareness of this SDI feature could help to track the real sources of some of the problems that SDIs may face.

Viewing SDI as CAS has major implications for SDI assessment. The methods for assessing CASs require specific strategies that are different from those used for less complicated, linear and predictable systems. Many standard assessment tools, techniques and methods rely on the assumption that the evaluated phenomenon is linear, closed and predictable. Because these assumptions may not be valid for complex phenomena like SDI, we should consider a number of principles underlying the assessment of complex adaptive systems (Eoyang & Berkas, 1998). For example, the assessment framework should be flexible because complex adaptive systems are not stable and their baseline (objectives, definition, etc.) may change over time. The assessment framework should also include multiple strategies and approaches to allow assessment from many different perspectives. Cilliers (1998) and De Man (2006a) argue that complex problems can only be investigated using complex resources such as multifaceted views. Therefore, when analysing complex phenomena like SDI we should not try to simplify the complexity, but acknowledge it and deal with it. Oversimplification of the assessment framework should be avoided because it might not reflect the complexity and variability of the assessed phenomena. We therefore recommend that the results of this research be taken into account when designing an SDI assessment framework.

## 2.8 Conclusions

The complexity of SDIs has become a generally accepted fact, but so far little is known about what to do with this fact. This research provides a new insight into the mechanisms and functionality of SDIs from the perspective of Complex Adaptive Systems. By means of case study analysis and consulting experts it was possible to investigate the possibilities of using CAS theory to describe SDI. Most of the characteristic features and behaviours of CASs could also be identified in SDIs. Based on such evidence, we can conclude that CAS theory is applicable to describe SDI.

The fact that an SDI can be viewed as a CAS has implications for various studies regarding SDI, especially its assessment. New assessment strategies, preferably derived from the research on complex systems, should be further investigated with a view to their possible application in SDI assessment to improve the validity of such assessments. In addition, the in-depth analysis of CAS features and behaviours identified and analysed in this study may lead to a better understanding of SDIs.

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# Chapter 3

# Multi-view SDI Assessment Framework

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# 3 Multi-view SDI Assessment Framework

## 3.1 Introduction

Over the last few years Spatial Data Infrastructures (SDIs) have become an important issue in Geo-Information Science, its significance was demonstrated by numerous initiatives all over the world at global, regional, national and local levels. The growing number of clearinghouses may be a good indicator for the development of Spatial Data Infrastructures. According to Crompvoets (2006) the number of national SDI clearinghouses increased rapidly from the first initiative in 1994 in the USA to 83 national clearinghouses in April 2005. Large sums of money have been invested into SDI initiatives over the last few years. Worldwide around €120 million is spent each year just on clearinghouse management (Crompvoets, 2006). The investment requirements for an Infrastructure for Spatial Information in the European Community (INSPIRE) at European, national, regional and local levels are estimated to be from €202 to €273 million each year (Cragila, 2003). Given this expenditure and society's interest in the proper and effective use of public funds, it is imperative that these SDI initiatives should be assessed (Shadish et al., 1991). SDI assessment is an increasingly hot topic because SDIs are mainly established by governmental bodies and resourced from the public funds, and the demand for such research is increasing. For example, implementation of the European directive establishing an Infrastructure for Spatial Information in the European Community will require monitoring and require regular reporting (European Commission, 2007).

Many researchers have tried to assess SDIs (Crompvoets, 2006; Steudler et al., 2004; Rodriguez Pabón, 2005; Delegado-Fernandez & Crompvoets, 2007; Delgado Fernández et al., 2005; Kok & van Loenen, 2004; Masser, 1999; Onsrud, 1998; SADL, 2005). All these attempts, however useful and valuable, either concentrate on one aspect of SDI (Crompvoets, 2006; Delegado-Fernandez et al., 2005), or are bounded by one region (SADL, 2005),or describe SDI development in few particular countries (Masser, 1999; Onsrud, 1998), or are still conceptual in nature (Kok & van Loenen, 2004; Rodriguez Pabón, 2005; Steudler et al., 2004). What is needed is a multidisciplinary framework that could evaluate the full extent of SDIs worldwide.

Assessment and evaluation of SDI initiatives is problematic for a number of reasons. Even within the SDI community there are differences in the understanding of SDI and its potential benefits. Cragila and Nowak (2006) raise this issue when reporting on the key findings of the International Workshop on SDI's Cost-Benefit. They argue that there is much confusion resulting from the lack of an agreed definition of SDI, its components and the relationships between them. Moreover, different studies on SDI assessment identify different benefits and assign them to different categories. Similar conclusions are formulated in the report of the workshop 'Exploring Spatial Data Infrastructures' (Grus et al. 2006). This makes it difficult to identify uniform criteria of merit for SDI inputs, utility, outputs and outcomes. SDI is also difficult to assess because of its complexity and dynamic and constantly evolving nature. SDIs also differ between countries as the same implementing rules may cause different results. For example, at the European level, the INSPIRE directive lays down general rules for establishing an SDI for the European Community (European Commission, 2007). Nevertheless, despite the fact that SDIs in the member states will behave and operate in a similar general way as indicated by the directive, they will never be the same, and sometimes will differ considerably depending on political, economical and cultural national circumstances. The directive acknowledges this diversity and assumes that INSPIRE will be build upon SDIs that are established and operated in member states.

In this paper we try to build a coherent SDI assessment framework that acknowledges this complexity. First we identify and analyse the key SDI characteristics that underlie the dilemmas affecting the assessment strategy. To deal with these dilemmas we examine SDI through the lens of Complex Adaptive Systems (Grus et al., 2010). From this analysis we construct an assessment framework based on the principles of evaluating Complex Adaptive Systems (Eoyang & Berkas, 1998; Cilliers, 1998; De Man, 2006b) and evaluation theory applying to multiple-approach evaluation, using existing SDI evaluation approaches.

In section 2 we introduce the key characteristics of SDIs that influence the way in which SDI should be evaluated: multi-definitions, multi-objectives, complexity and dynamism are the issues of interest. Section 3 presents the theory of Complex Adaptive Systems (CAS) and its assessment issues, with a discussion on the issue of using multiple approach strategy in general evaluation practice. Section 4 presents the prototype evaluation framework for SDI infrastructures. The article closes with a discussion, conclusions and recommendations, especially on the potential difficulties with applying the framework. We do not discuss the drawbacks or benefits of the particular approaches as these will become evident after use of the framework.

In this paper we use several terms regarding the evaluation domain. For clarity, we explain the following terms used in the text:

- SDI assessment framework – a construct of various assessment approaches and methods built around CAS assessment principles and general assessment theory to structure and organize SDI evaluation.
- Assessment purpose or perspective – one of three main purposes or perspectives for performing an assessment: accountability, knowledge and development.
- Assessment approach – whole methodology of assessing particular SDIs from a certain viewpoint, e.g. SDI development, clearinghouse, or performance.
- Assessment methods – the techniques used in SDI assessment approaches to collect indicators. They include different types of surveys such as questionnaires and web surveys, document studies such as country reports, key informants having unique knowledge related to the issue being evaluated, such as SDI coordinators, and case studies (Frechtling & Sharp, 1997).

Whenever the terms 'evaluation' and 'assessment' are used, they both refer to the characterization and judgement of the merits of SDI.

## 3.2 SDI Nature and assessment issues

Assessing SDI, especially in worldwide comparison or benchmarking studies, remains problematic. The reason for this might be the nature of SDIs, particularly their multifaceted and dynamic nature, complexity and vaguely defined objectives. Hansen (2005) stresses that the characteristics of the evaluated object determine the choice of the evaluation models. Therefore, before proposing the SDI assessment framework, it is necessary to explore these SDI characteristics in more detail to enable a justification of the choice of the assessment strategy.

SDI is defined in multiple ways. For example, Chan (2001) collected the 11 most popular SDI definitions by different organizations and authors in different parts of the world at different times. Each of these definitions describes

SDI from slightly different aspects and none of them describe SDI completely. The variety of ways in which SDI is defined reflects its multifaceted character (De Man, 2006a). Rajabifard et al. (2002) claim that some SDIs may be treated as products while others as processes, which raises fundamental questions about SDI evaluation. To be able to assess and compare the objects of the evaluation, an agreement must be reached on single definitions of these objects and about criteria and values of merit. Referring back to Rajabifard's classification, are we assessing SDIs as products in terms of their structure or the processes they should facilitate? The criteria and values of merit may therefore depend on how we understand the SDI concept.

It can be stated that the conceptual objective of Spatial Data Infrastructure is to enhance access to and the sharing of spatial data produced by various agencies. The principal purpose of SDIs may be defined in different ways, for example: 'let geographic information promote economic development, improve our stewardship of natural resources, and protect the environment' (Clinton, 1994); 'to help avoid fragmentation, gaps in availability of GI, duplication of data collection and problems of identifying, accessing or using the available data' (SADL, 2003); and 'to support information discovery, access, and use of geographical information for example in crime management, business development, flood mitigation, environmental restoration, community land use assessment and disaster recovery' (Nebert, 2004). Different countries do not define the objectives of their SDI in the same way. Some stakeholders may only accept the facilitating of data exchange role of SDI; others may see SDI only as a facility for spatial data production and storage. To allow the worldwide benchmarking of SDI, we will need a uniform definition of the objectives of SDI, but the variety of interpretations of what SDIs are suggest that it will not be possible to find a single definition of SDI that everybody will agree on. This means that the framework should be able to incorporate different understandings and views of the objectives of SDIs.

During the workshop on Exploring SDI held in Wageningen in January 2006, SDI complexity was indicated as being one of the main obstacles and challenges to its evaluation (Grus et al., 2006). The complexity of SDI is due to the dynamic and non-linear interactions between its entangled components. Chan and Williamson (1999b) state that its functionality becomes more complex over time as new SDI requirements emerge and are adopted by the users. As an SDI model moves from being data-centric to service-centric, complexity increases and identification and measurement benefits become more problematic

(Georgiadou et al., 2006). This means that the nature of SDI and the interactions between its components cannot be described in a simple and uniform way. Moreover, SDI has a different character and works in a different ways in different parts of the world. This complexity of SDI makes it difficult to implement in diverse environments in the same way and with the same results, which in turn makes assessment difficult because of the problems of attributing success or failure of SDI implementation to one or more concrete factors. In other words, because SDIs are complex it is difficult to track cause-and-effect relationships (Rodriguez Pabón, 2005).

The dynamic nature of SDI is reflected in the intensive flow of information between data producers and users (Masser, 2005a). According to Rajabifard et al. (2003b) and Chan (2001) the dynamic nature of SDIs is reflected in changes in SDI technology, people and their needs. As SDI requirements and expectations change, the mediation of rights, restrictions and responsibilities between people may also change. Such changes imply that the system's behaviour is unpredictable, which presents a challenge for assessment practice. The assessment framework should allow assessment practitioners to detect and analyse the predictable as well as the unpredictable changes. Another aspect of the dynamic nature of SDI dynamism is its evolving nature. Most assessment practices measure SDIs at one moment in time, but the SDI assessment framework should also be able to describe its evolution over time, for example through longitudinal assessment approaches.

## 3.3 Towards the assessment framework

There is strong evidence that SDIs behave like Complex Adaptive Systems (CAS) (Grus et al, 2010), and the principle of evaluating Complex Adaptive Systems (Eoyang & Berkas, 1998) underpins the design of the SDI assessment framework. Complex Adaptive Systems are open systems in which different elements interact dynamically to exchange information, self-organize and create many different feedback loops, in which relationships between causes and effects are non-linear, and where the system as a whole has emergent properties that cannot be understood by reference to the component parts (Barnes et al., 2003). Analyses of the structure and behaviour of Dutch, Australian and Polish SDIs indicate that the SDIs share the same behavioural characteristics as CAS (Grus et al., 2010). We therefore decided to use the principles of evaluating Complex Adaptive Systems for SDI assessment. These principles specify that the framework should be flexible and have a structure that permits frequent reconsideration and redesign, because the baseline (understanding, definition, and objectives) of CAS (and also SDIs) is constantly changing. The assessment programme should concentrate on both the expected and unexpected system behaviour. It should also capture long-term and short-term outcomes, from close and distant points of view: it should contain more general, regional or cross-national comparisons (distant view) as well as more detailed case study analyses of national or local SDIs (close view). At national and regional levels, the scale of the SDI dramatically affects the amount of detail that can be accommodated in the assessment. Wider national or transnational initiatives (e.g. worldwide assessment of benchmarking) require the involvement of a much broader stakeholder network, many more assumptions (not all of which will be accepted by all stakeholders) and much less specificity than local initiatives. Because of the complex interconnections, assessment programmes should include multiple strategies and approaches, including those for linear systems, and a variety of data should be collected to reflect the variability and complexity of the system. The assessment framework should also contain methods that can capture the patterns of causal relationships. But because these patterns of causation can change in CAS (SDIs) it is essential to capture the baseline (reference point) of these causal relationships (Eoyang, 1998). For example, it may be helpful to describe the relations between the five standard SDI components (people, standards, technology, policy and data) and then observe the emergent patterns, changes and evolution of these relationships. Detailed analyses of case studies may help to reveal these interactions and rules of causation.

The recommendations for complexity assessment given above are in line with Cilliers' (1998) analysis that truly complex problems can only be investigated using complex resources. This is a reinterpretation of the antireductionist position that a complex system cannot be reduced to a collection of its basic constituencies (e.g. SDI components) – not because the system is not constituted by them, but because too much of the rational information gets lost in the process. In the same way, the SDI assessment strategy must also be complex if it is to represent the system's variability and richness in information important from the assessment perspective. Accordingly, different assessment approaches and methods must be used simultaneously. This is also in line with De Man (2006b), who states that a multifaceted view is needed to understand concrete SDI initiative. The assessment framework should not try to capture and control complexity, but acknowledge multiple SDI realities shaped by heterogeneous and reflective actors. At the same time, it must be a manageable tool that contributes to a better understanding and assessment of the processes connected with SDI.

If we agree that SDIs are complex systems the discussion above implies the use of rather complex and multiple assessment approaches and methods would be a valid approach to assessing or analysing these complex systems (see Eoyang & Berkas, 1998; Cilliers, 1998; De Man, 2006b). It is interesting then to analyse the experience and practice of evaluation theory and research with multi-approach and multimethod assessment models. In other words: what does evaluation/assessment research says about multimethod assessment?

Scriven (1983) stresses that 'evaluation is a multiplicity of multiplies' in a number of ways: 'Evaluation is multifield, concerned with programs, products, proposals, personnel, plans, and potentials; multidisciplinary; with multidimensionality of criteria of merit; needing multiple perspectives before synthesis is done; multilevel in the wide range of levels of validity/cost/credibility among which a choice must be made in order to remain within the resources of time and budget' and in the different levels of analysis, evidential support, and documentation appropriate in different circumstances; using multiple methodologies, multiple functions, multiple impacts, multiple reporting formats: 'Evaluation is multiplicity of multiples' (Scriven, 1983). This multiplicity of evaluation is in line with the characteristics of SDI mentioned above: its multifaceted nature, the multiple purposes of evaluation, multiple definitions and multiple objectives.

Assessment of the multiple dimensions of the assessed object is also epistemologically motivated. The more vantage points that are taken, the better the constructed picture of truth will be. For example, the reality might be that one particular SDI has a very well developed clearinghouse, but an inadequate legal framework for access policy. In such cases, assessing only the access network (clearinghouse) of this particular SDI would draw a false picture of reality. Using multiple evaluation models also reduces potential biases in evaluation (Shadish et al., 1991) in case some methods generate considerably different results than others.

The multi-approach and multimethod assessment strategy is well recognized by evaluation practitioners. Datta (1997) confirms moderately high to high acceptance of mixes of methods, analysis and data in evaluation practice, but the difficulty of defining the quality of such multimethod studies should be recognized. Using multiple analyses (descriptive analysis and various statistics within one evaluation) is highly acceptable, although the need to deal with the biases inherent in different techniques is borne in mind. Using multiple data is also highly acceptable, as long as due consideration is given to the weighting of different data sources. Based on Datta's evaluation experience, the benefits of using multimethod analysis seem to be depth, methodological equity and transparent findings from all methods.

Assessments are made for many specific reasons, for example to measure and account for the results and efficiency of public policies and programmes, or to gain explanatory insights into social and other public problems, or to reform governments through the free flow of evaluative information (Chelimsky, 1997). Chelimsky (1997) distinguishes three general classes of evaluation purposes that cover all of the specific purposes: the accountability purpose of evaluation, the developmental purpose of evaluation, and the knowledge purpose of evaluation. Accountability evaluation measures the results of the programme by asking cause-and-effects questions. The developmental class comprises strategies to measure and recommend changes in organizational activities and to monitor how projects are being implemented across a number of different sites. The purpose of knowledge evaluation is to generate a better explanation of the programme or to acquire a more profound understanding in some specific area or field (Chelimsky, 1997). These three classes of purposes are not mutually exclusive with regard to methods, but they may be needed at different times. For example, evaluation for knowledge or evaluation for development may be needed before evaluation for accountability. Georgiadou et al. (2006) present a different taxonomy of evaluation purposes. They classify existing SDI evaluation approaches through a taxonomical lens from information systems evaluation research and explore four types of evaluation approaches: control, learning, sense-making and exploratory approaches. In principal, Chelimsky's and Georgiadou's classification are comparable. Control evaluation and Chelimsky's accountability approach ask questions about achieving the goals of the programme. Georgiadou's learning and exploratory evaluation and Chelimsky's knowledge approach set out to learn and create knowledge about the assessed phenomena. Both Georgiadou's sense-making evaluation and Chelimsky's developmental evaluation aim to modify and improve the evaluated phenomena.

For the purpose of this paper we will use Chelimsky's three classes: accountability, knowledge and developmental, as they originate from the evaluation theorists and seem to be more generic.

All the purposes of evaluation described above are valid for SDI assessment. There is a demand for accountability evaluation (Lance et al., 2006) to justify and monitor in a systematic way the relations between the investments in SDI initiatives and the results obtained. The assessment approaches that fall into the accountability class may help to answer questions such as did the use of spatial data increase as a result of implementation of a more liberal access policy to spatial data, and what is the impact of implementation of new SDI agenda on stakeholders' activities? Questions about the efficiency and effectiveness of various SDI activities are also valid for accountability approaches. Developmental evaluation is needed to monitor the transitions of SDI initiatives, such as transition through generations described by Rajabifard et al., (2002). The analysis of the development, transitions and changes of SDI may help to capture and better understand its dynamic nature, and in monitoring whether SDI is being implemented according to the intended direction and recommend ways of SDI development. The primary functions of the developmental assessment approaches should be to measure and recommend changes in SDI activities and development, to monitor in a continuous way how SDIs are being implemented across many countries, and to find out whether SDI implementation is being realized according to the agenda. Knowledge evaluation is crucial for a better understanding of the mechanisms and forces behind SDI. Better understanding of the mechanisms and rules behind SDI frameworks allows action to be taken to improve them. 'Once one understands the nature of the evaluand (evaluand = object of the assessment), one will often understand rather fully what it takes to be a better and a worse instance of that type of evaluand. To exemplify, understanding what a watch is leads automatically to understanding what the dimensions of merit for one are – time-keeping, accuracy, legibility, sturdiness, etc.' (Scriven, 1980). The assessment of SDI could therefore contribute significantly to increasing our knowledge about the key qualities of SDI. The need to better understand the ideas and mechanisms behind SDI is also stressed by Georgiadou et al. (2006), who argue that more attention should be paid to conducting exploratory evaluations of SDI.

The remainder of this paper will focus on the presentation and description of the prototype framework, which acknowledges and deals with the SDI assessment issues discussed above.

### 3.4 Multi-view SDI assessment framework

The previous chapters justified the use of multiple assessment approaches, considering the multifaceted and complex nature of SDI. This section presents the assessment framework that potentially fulfils all of the requirements mentioned in the previous paragraphs. A multi-view framework is proposed in order to assess SDI. Figure 3.1 presents the conceptual model of the framework. The main idea behind the framework is that it covers all three purposes of assessing SDI: accountability, knowledge and development. It also acknowledges the multifaceted character of SDI.

The core of the proposed assessment framework is represented by the multiple assessment approaches that focus on different SDI aspects (facets). To overcome the problem of multiple definitions, SDI is treated here as a complex system with multiple facets. Because we concentrate here on SDI assessment, the facets are related to the assessment approaches included in the framework. Each approach treats SDI from different view. Principally, we concentrate only on the specific objectives for each approach that SDI should meet in order to be good. For example, the Clearinghouse Approach concentrates only on the SDI's data access facility; for this approach the objectives of good SDI are related only to data access technology. The essence of the multi-view framework is that it accepts multiple views on SDI and thus accepts its complexity in terms of multiple definitions. Moreover, each approach covers at least one of the three purposes of the assessment: accountability, knowledge and development. All approaches use one or more assessment methods, such as case studies, surveys, document analysis, etc., to evaluate SDIs. The proposed assessment methods are both qualitative and quantitative.

The Generational Approach is based on the generational development of SDIs described by Rajabifard et al. (2002). The worldwide development of SDI can be measured according to the identified indicators of first, second and future generations of SDI development. The results of such an assessment will help the countries concerned to position themselves on the worldwide arena and to indicate directions for future development. Moreover, iterative and longitudinal application of the Generational Approach can measure the dynamics of the worldwide development of SDI initiatives. The measurement of transitions through generations may help to capture the factors that strengthen or weaken the development of SDIs. The generational assessment approach falls into the developmental class of evaluation. It seeks to answer questions about setting a developmental agenda for SDI development, how to measure changes and to monitor SDI implementations across a number of countries. The knowledge purpose is also valid for the Generational Approach. Questions like why one SDI implementation scheme works in Europe but not in Africa may be also answered by this approach. In this approach the worldwide survey and document study may be used to collect data.

The Programme Evaluation approach emerged from the burst of social programmes in 1960s in the USA. The basic function of Programme Evaluation is to check the accountability of social programmes launched in the education, income maintenance, housing, health and criminal justice sectors (Shadish et al., 1991). The Programme Evaluation approach can be defined as a determination of the worth of any enterprise (programme) that aims at solving a particular problem or improving some aspects of the area of interest (Worthen, 1990). This approach treats SDI as a public programme aimed at improving the access to and the sharing and usability of spatial data. Various sub-approaches can be distinguished to conduct a Programme Evaluation.

Worthen (1990) identifies a Performance-Objective Congruence Approach, a Decision-Management Approach, a Judgement-oriented Approach, Adversarial Approaches and Pluralist-Intuitionist Approaches. One technique for analysing programmes might be to build a logic model consisting of information on inputs, activities, outputs and outcomes. For each of these components a set of indicators can be found to assess the performance of SDIs. The Programme Evaluation approach falls into the accountability and knowledge purposes of the assessment as it answers the questions of whether the programme works and increases our knowledge about its components. Case studies mixed with surveys are the most common method of conducting a Programme Evaluation.

The SDI-Readiness Approach is an existing model that assesses whether a country is ready to embrace SDI development (Delegado-Fernandez et al., 2005; Delgado Fernández & Crompvoets, 2007). When building an SDI readiness index, various factors like organization, information, access network, people and financial resources are taken into account. Each of these factors consists of a number of indicators that can be quantitatively measured. This model falls within the knowledge and developmental evaluation purposes. The results can be used to answer questions about comparing the progress made with implementing SDIs by different countries. It also helps to identify obstacles in SDI programmes implementations. SDI-readiness is measured by collecting and analysing predefined indicators based on surveys.

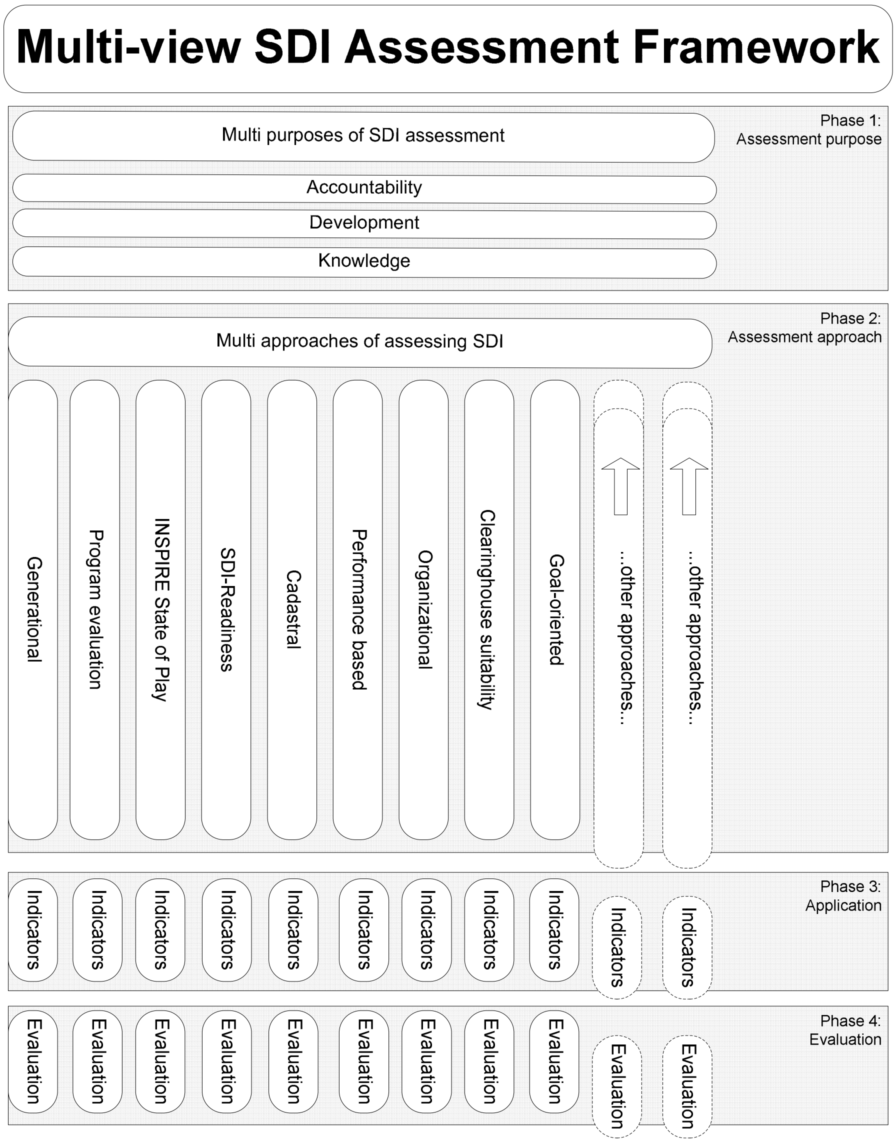


Figure 3.1 Multi-view SDI assessment framework

The Cadastral Assessment Approach was originally developed as a land administration evaluation framework by Steudler et al. (2004). It presents a number of indicators for five areas in evaluating Land Administration Systems (LAS): the policy level, the management level, the operational level, influencing factors and assessment of performance. The reason for including this approach in the SDI assessment framework is that there are significant similarities between efficient and effective SDIs and Land Administration Systems and therefore there is a strong ground for using LAS evaluation and performance indicators for SDIs

(Steudler 2003). However, this approach is still a conceptual one and has not even been used for evaluating LASs. It still needs to be developed and operationalized for application in practice. If applied it may give us answers about the performance of SDIs, as it contains a number of performance assessment indicators (accountability purpose of evaluation), and increase our knowledge about the policy, management and operational levels of SDIs (knowledge purpose of evaluation). The survey method will be used to measure predefined indicators on a worldwide scale.

The Organizational (Institutional) Approach is based on Kok and van Loenen's (2004) research into the assessment of the different stages of development of geographic information infrastructures, when viewed from the institutional (organizational) perspective. This approach focuses on measuring the development of the following GII (SDI) aspects: vision, leadership, communication, self-organising ability, awareness, financial sustainability and status of delivery mechanism. This approach falls into the developmental perspective of evaluation as it measures SDI development from an organizational (institutional) perspective. So far, the authors of this approach have measured and analysed the development of five SDIs using the case study method (van Loenen, 2006).

The Performance-Based approach uses the Performance-Based Management (PBM) technique to evaluate, demonstrate and improve the performance of SDI (Giff, 2006). This approach is based on the assumption that SDI is an infrastructure and that methods like PBM normally used for assessing the performance of infrastructure can be used for assessing SDI. This method aims at developing performance indicators based on specific SDI objectives, which are used to measure the effectiveness, efficiency and reliability of SDIs. This approach is still in the conceptual stage and specific indicators and methods to measure them have yet to be developed. It falls under the accountability evaluation purpose as it mainly seeks to answers questions about SDI efficiency and results.

The Clearinghouse Suitability Approach is based on research by Crompvoets et al. (2004) into measuring and assessing the development of National Spatial Data Clearinghouses worldwide. A method for measuring a specific set of quantitative indicators of clearinghouse portals can be applied as a continuation of longitudinal studies started in 2000. This developmental assessment aims at showing the advances and trends in the development of clearinghouses (and web portals). This assessment approach uses survey (website visit) and contacting key informants to measure indicators of the development of clearinghouse and web portals.

The State of Play Approach is a study covering the period from mid 2002 to mid 2005 to describe, monitor and analyse activities related to National Spatial Data Infrastructures in 32 European countries: 25 EU member states, 3 Candidate Countries and 4 EFTA countries. The major activity of this study is to collect and structure all the relevant information on the status of the six building blocks that together, according to this approach, constitute an SDI: the legal framework and funding, reference data and core thematic data, metadata, access and other services, standards, and thematic environment (SADL, 2005). The same approach and methods can be used as a component of the multi-approach framework, also in regions of the world outside Europe. Document studies (country reports), surveys (website visits) and contacting key informants (national SDI experts) are the methods used in this approach.

Pabón (2005) present a theoretical framework to assess SDI initiatives by identifying and describing common success criteria across different contextual backgrounds. According to this framework, SDI initiatives must be evaluated in their two major dimensions: the quality dimension and virtue dimension. The quality dimension covers the efficiency and effectiveness of technical and organizational aspects of SDI projects. The virtue dimension consists of political, human and social aspects, which are measured against predefined qualitative criteria.

Table 3.1 summarizes the attributes of all the evaluation approaches proposed for the multi-view framework. Some of the approaches presented exist only as theoretical constructs and need to be elaborated further to develop application methods. These include the Generational, Cadastral, Performance-Based and Organizational approaches. The SDI-Readiness and Clearinghouse Suitability approaches can be applied in the framework in a straightforward manner because the methodologies and application practices already exist. The Programme Evaluation approach still needs to be developed and methods of measurement and assessment need conceptualization. This variety of assessment methods guarantees that a wide range of data on SDIs can be collected. The set of approaches constituting the framework also covers all three classes of evaluation purposes presented by Chelimsky (1997): accountability, knowledge and developmental purposes.

The application part of the assessment framework focuses on measuring the indicators for each assessment approach. The selection criteria for the indicators are the criteria of merit: the descriptors of an evaluand that reflect its capacity to meet needs (Shadish et al., 1991). For example, if interoperability is the criteria of merit of SDI it should be measured with an indicator that best reflects the level of interoperability.

Table 3.1 Summary of evaluation approaches proposed for the multi-approach assessment framework

| Approach | Goal Description | Method | Status | Assessment purpose class |
|---|---|---|---|---|
| **Generational** | To measure the development of SDIs worldwide | Survey, document study | Not developed | Developmental Knowledge |
| **Programme Evaluation** | To determine the worth and accomplishment of the objectives of SDIs | Case study and survey | Not developed | Developmental Knowledge Accountability |
| **SDI-Readiness** | To assess if the country is ready to embrace the SDI development | Survey | Applicable | Developmental Knowledge |
| **Cadastral** | To measure five evaluation areas of LAS | Survey | Needs improvement | Knowledge Accountability |
| **Organizational** | To measure SDI development from the institutional perspective | Case study | Applicable | Developmental |
| **Performance-Based** | To measure SDI effectiveness, efficiency and reliability | Not available | Needs improvement | Accountability |
| **Clearinghouse Suitability** | To measure the development and impact of SDI clearinghouses worldwide | Survey, key informants | Applicable | Developmental |
| **State of Play** | To measure the status and development of SDIs | Document study, survey, key informants | Applicable | Developmental Accountability |
| **Pabón's** | To measure quality and virtue dimensions of SDI | Case studies, Web survey | Needs improvement | Developmental, Knowledge |

The scale of the measure should be defined to allow comparison and ranking of the measured values. The result of the measurement of selected data forms the basis for the assessment of a particular SDI. The best approach and method can be chosen according to the purpose of the evaluation of the SDI (accountability, development or knowledge).

The evaluation part of the framework has two functions: (1) evaluation of the SDI and (2) evaluation of each approach and the whole assessment framework. The first function is the primary one as the main purpose of the research is to assess SDIs. The evaluator makes a judgement on SDI, taking into account the standard of merit determined for each criterion of merit for the particular assessment approach. For example, if interoperability is being measured, each measured value should be placed on a defined scale to make it possible to assess (evaluate) and compare the value of interoperability, either between countries or as a reference to some standard value (benchmarking). A more holistic and bias free picture of specific SDI initiatives can be obtained by interpreting the assessment results for those SDIs from different viewpoints. This will enhance our understanding and assessment of the SDIs.

The second function of the evaluation part is the evaluation of the assessment approaches and the whole framework itself, or meta-evaluation, to ensure that they are acceptable to the stakeholders. Meta-evaluation refers to a variety of activities intended to evaluate the technical quality of evaluations and the conclusions drawn from them. Its purpose is to identify any potential bias that there might be in an evaluation and, using a variety of methods, to estimate their importance (Straw & Cook, 1990). Meta-evaluation can also provide information about the impacts of evaluation activities. Several models of meta-evaluation exist (Cook & Gruder, 1978), but at this early stage in the development of the multi-approach assessment model it is difficult to choose the most suitable one. Nevertheless the meta-evaluation must be performed, especially by the users of the framework, and must follow the application of the multi-approach framework. However, given that the principal feature of the proposed framework is the use of multiple approaches, the same indicators can be used for different assessment approaches and methods. Coming to similar conclusions about the value of one particular SDI using multiple assessment approaches would therefore confirm the validity of the whole assessment framework. This design is in fact a kind of built-in self-evaluation mechanism: the use of multiple, independent approaches and methods used by a number of evaluators guarantees SDI assessment results that accurate reflect reality and have a low bias. The potential overlap between the methods used for different assessment approaches may help to validate the approaches themselves. Moreover, this assessment framework design is related to triangulation research methodology which applies and combines several research methodologies in the study of the same phenomenon. Triangulation is the preferred line of research in the social sciences because combining multiple observers, theories, methods and data sources can overcome the intrinsic bias inevitable in single-method, single observer and single-theory investigation (Denzin, 1990). Evaluation of the assessment framework and its approaches is crucial for their future usability because stakeholders will only use its results to improve SDI's performance if they accept the framework.

## 3.5 Discussion

The core element of this paper is the presentation of the conceptual model of the SDI assessment framework. The authors intend to apply the assessment framework in their future research to assess SDIs at the national level (NSDIs). The multi-view assessment strategy was based on the principles of assessing Complex Adaptive Systems and general evaluation research. A combination of multiple approaches and methods generates more complete, more realistic and less biased assessment results. Multiple assessment methods – case studies, surveys, key informants and document studies – capture the multifaceted and complex character of SDI. They guarantee a diversity of SDI data, which in turn can reflect the complexity of the SDI. The framework is flexible because it permits evaluation approaches and indicators to be added, removed or corrected – an especially important feature when the framework is applied iteratively and refined successively. The relative complexity of the assessment framework presented here also meets the requirement that truly complex systems should be explored and understood with complex methods to properly reflect reality. The aim of the proposed framework is not only to assess SDI performance, but also to deepen our knowledge about SDI mechanisms and support SDI development.

Some obstacles and difficulties may be encountered when applying the assessment framework. The issue of timing is the first important consideration, especially in such a dynamic and constantly evolving environment like SDI. The simultaneous use of several assessment approaches will generate more realistic results than if they are conducted sequentially. Therefore the intervals between data collections for various approaches should be as short as possible to allow application of the multiple approaches to be synchronized. The next consideration is the difference in data availability between various assessment approaches and methods. Because the SDI concept is still very young, some countries may not produce reports or any other data that could be used in the assessment analysis. For some assessment approaches and their methods it may be impossible to collect reliable and complete data, such as reports on SDI finances, expenditure or revenues figures, and there may be no internal self-assessment reports available. The last consideration concerns the integration of multiple approaches. The intended outcome of the integration of all the assessment approaches included in the framework is to give tangible information on the merits of the SDIs. It is possible, though, that the findings of several assessment approaches will present different pictures of SDI. These differences must be reported so that future investigators can build on such observations (Denzin, 1990).

An important aspect of applying the assessment framework in practice is promoting the use of the evaluation results, and so evaluators must take active steps to increase the use of their results. Shadish et al. (1991) state that evaluators can facilitate the use of evaluations by choosing the right communication channels to disseminate the results and by taking the appropriate stance when dealing with potential users. The appropriate role for the evaluator to adopt is as a servant. The preferred communication channels are writing and presenting evaluation reports, making recommendations for action, publicizing evaluation findings and maintaining close contacts with users to stimulate the use of the results of the assessment.

## 3.6 Conclusions

In this paper, we have highlighted four characteristics of SDI that make its assessment specific: its complexity, its many definitions, the often vague objectives and its dynamic nature. To deal with these issues we suggested that the framework should be based on the principles of assessing Complex Adaptive Systems: using multiple assessment strategies, a flexible framework and a multi-perspective view of the assessed object. We argued that the application of the proposed framework would lead to a more complete, realistic and less biased assessment of SDI. We proposed a number of existing and non-existing SDI assessment approaches as building blocks for the framework. We also discussed issues related to the application of the framework in future research. Despite the fact that the multi-approach assessment framework is strongly supported in complexity theory and evaluation practice, and its application results are promising for evaluating SDIs worldwide, we also suggest that the issues of harmonizing the different approaches at one point in time, the difficulties of collecting data for all approaches for all countries and the integration of the results should be examined critically during future application of the assessment framework.

# Evaluation of the Multi-view SDI Assessment Framework

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# 4 Evaluation of the Multi-view SDI Assessment Framework

## 4.1 Introduction

Over the last decade Spatial Data Infrastructures (SDIs) have become an important aspect of geo-Information science and practice. Its significance has been demonstrated by numerous initiatives all over the world at global, regional, national and local levels (Groot, 1997; Masser, 1999, 2005a; 2007; Rajabifard, 2002; Crompvoets, 2006; Onsrud, 2007). Now, when many SDIs have been established, SDI assessment is increasingly important to judge if the SDIs realize the intended objectives and benefits. SDI assessment can be performed for the following reasons: to obtain more knowledge about SDI functioning, to see if SDIs are on the intended track of development, to assist SDI development, or to check for accountability reasons (Georgiadou et al., 2006; Lance et al., 2006; 2009; Grus et al., 2007). SDI assessments gradually become an integral part of SDI policies. For example, the European directive establishing an Infrastructure for Spatial Information in Europe (INSPIRE) requires monitoring and regular reporting on the progress of INSPIRE implementation and the use of the infrastructure (European Commission, 2007, 2009). Another example is GIDEON – the policy document for establishing the national SDI in the Netherlands – which also sets formal requirements relating to monitoring and reporting (VROM, 2008).

Many researchers have tried to develop and apply approaches to assess SDIs (see Crompvoets et al., 2008a; Onsrud, 1998; Masser, 1999; Kok & van Loenen, 2005; Steudler et al., 2004; Delgado Fernández et al., 2005; Rodriguez Pabón, 2005; Crompvoets, 2006; Delgado Fernández and Crompvoets et al., 2007; Vandenbroucke et al., 2008b). All these attempts, however useful and valuable, either concentrate on one aspect of SDI (Kok & van Loenen, 2005; Delgado Fernández et al., 2005; Crompvoets, 2006), are bounded by one region (Vandenbroucke et al., 2008b), are describing SDI development in few particular countries (Onsrud, 1998; Masser, 1999), or are still conceptual in nature (Steudler et al., 2004; Rodriguez Pabón, 2005). In order to evaluate many SDI aspects a comprehensive assessment framework is needed. However, comprehensive assessment and evaluation of SDI initiatives is problematic due to its multi-faceted, complex and dynamic nature (De Man, 2006a; Grus et al., 2008).

## 4.2 Multi view SDI assessment framework

As a response to the challenges of comprehensive SDIs assessment a Multi-view SDI assessment framework has been proposed (Grus et al., 2007). The framework acknowledges the complex, multi-faceted and dynamic character of SDIs. The rationale of the framework is based on a theoretical research on the nature of SDI. It has been shown that SDIs behave and can be described as Complex Adaptive Systems (CAS) (Grus et al, 2010). This behaviour implies that the evaluation principles of CAS may also be used to evaluate SDIs. The principles of assessing Complex Adaptive Systems differ largely from the methods used for assessing less complex and more linear systems (Eoyang & Berkas, 1998; Cillers, 1998). For example, oversimplification should be avoided, as many as possible vantage points should be taken and flexibility should be incorporated into an assessment framework. The Multi-view SDI assessment framework design is based on these principles.

Figure 4.1 presents the Multi-view SDI assessment framework. The framework consists of several assessment approaches. Each approach corresponds to at least one assessment purpose. Each assessment approach consists of a specific set of indicators and methods to measure those.

The first phase of the Multi-view SDI assessment framework implementation is to determine the purpose of SDI assessment. The framework identifies three purposes of assessing SDIs: 1) accountability – to measure the effects of SDIs, 2) knowledge – to get a better understanding of the SDI nature and functionalities, 3) development – to recommend changes in SDI functionality.

For example, the Clearinghouse suitability approach is classified as developmental because it assesses the developments of SDI's data access facility (Crompvoets & Bregt, 2008) and allows for determining the critical factors influencing their success (Crompvoets et al., 2004). In the next phase an assessment approach(es) which best fits the determined purpose of the assessment should be chosen. In case of the framework visualized in Figure 4.1, a set of existing SDI assessment approaches from various authors constitute the framework. In the next phase, the approaches are applied by measuring the values of their indicators. Finally, the evaluation of SDI is performed by interpreting the indicator values.

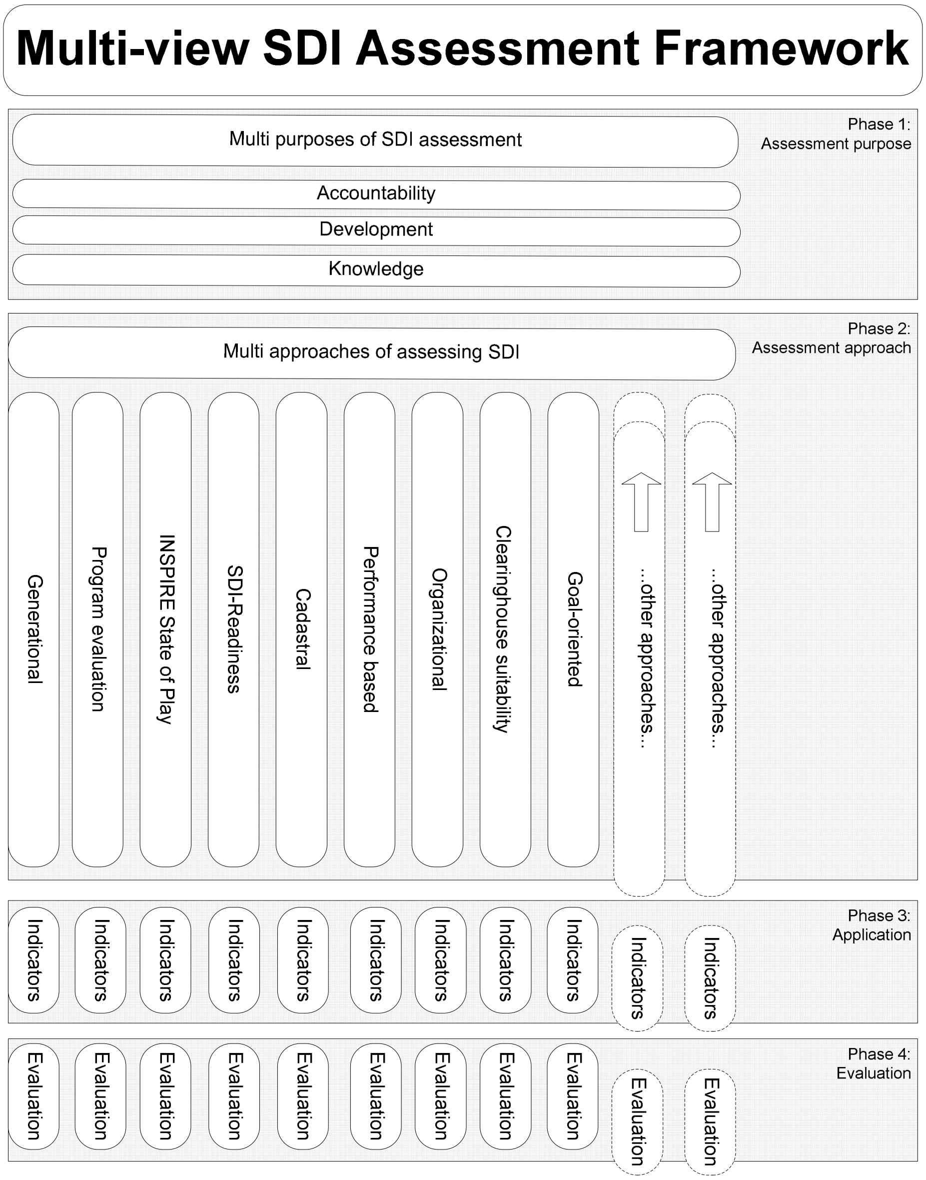


Figure 4.1 Multi-view SDI assessment framework adapted from Grus et al. (2007).

It has to be noted that according to the CAS theory the application of all available assessment approaches would give the most complete and most truthful assessment of SDI. In this way the SDI assessment is less biased and various SDI aspects are covered. However, it is also possible that the user selects and applies a selection or combination of assessment approaches which fits his assessment purpose the best. For a detailed description of the Multi-view SDI assessment framework the author refers to Grus et al. (2007).

Until now, the Multi-view SDI assessment framework has only been proposed as a concept. The application of the multi-method frameworks may be challenging for a number of reasons: 1) the high costs (in terms of time and resources) of multi-method studies; 2) the academic pressure to publish disciplinary rather than inter-disciplinary [multi method] research; 3) the lack of multi-method research knowledge; 4) the incompatibility between methods (Gil-Garcia & Pardo, 2006). Concerning the Multi-view SDI assessment framework several potential difficulties about its application have also been stated (Grus et al., 2007). For example, the time aspect of assessment is important because SDIs are considered to be dynamic and the values of indicators change over time. The next concern is the different level of data availability for the various assessment approaches. For some assessment approaches it might be difficult to collect all the needed data. For this reason the usability of some assessment approaches in the Multi-view SDI assessment framework may be limited.

Therefore, the framework needs to be evaluated before it can be used as an appropriate way of assessing SDIs. Evaluation of the assessment framework is also crucial for its future usability because stakeholders will only use the framework if they accept and trust it (Grus et al., 2007).

The objective of this paper is to evaluate the Multi-view SDI assessment framework in terms of the application process and its applicability.

In the following section the concept of evaluating the assessment framework is described. Next the methodology used to conduct the evaluation is presented. Then the results of the Multi-view SDI assessment framework evaluation are presented and discussed. The final section presents the main conclusions and recommendations for further research and use of the framework.

In the remainder of the article the name 'Multi-view SDI assessment framework' will be often substituted with 'the framework'.

## 4.3 Evaluating the evaluations

Evaluation can be defined as a careful examination of a program, institution, organization or policy with the purpose of learning about the particular entity studied (Walberg & Haertel, 1990). The focus of evaluation is on understanding and improving the evaluated object and/or on summarizing, describing and judging its outcomes. As Stufflebeam (2001) stresses, to achieve and sustain the status of professionalism, the products, programs and services should be subjected to evaluation. The same pertains also to evaluations themselves. In this context the Multi-view SDI assessment framework can also be an object of an evaluation. Evaluating the framework has a purpose of assuring the acceptable level of quality, proving its validity, and earning the credibility among the potential users of the framework. The concept of evaluating the evaluation is also named meta-evaluation. For the purpose of this paper meta-evaluation will be treated as a special case of evaluation. It is also assumed that different types of evaluations are valid also for meta-evaluations.

Meta-evaluation has been defined by Scriven (1969; 1991) as a second-order evaluation i.e. evaluation of evaluations. The purpose of meta-evaluation is to document the strengths and weaknesses of evaluation processes with the purpose of improving evaluation practice (Hanssen et al., 2008). Meta-evaluation represents an ethical as well as a scientific obligation. From the ethical point of view it is necessary to know the strengths and weaknesses of the evaluation method because the evaluation results often serve as a basis for decisions which may impact whole societies. From a scientific point of view it is necessary to know, for instance, how closely the assessment results correspond to reality. Stufflebeam and Shinkfield (2007) distinguished two types of meta-evaluations: proactive and retroactive. The proactive meta-evaluation concentrates on not yet fully applied evaluations and aim to help evaluators focus, design, budget, carry out and improve sound evaluations. Retroactive meta-evaluations focus on completed evaluations and check if the evaluation achieved the intended goals. The evaluation literature labels proactive and retroactive meta-evaluations also as formative and summative respectively (Scriven, 1980; Stufflebeam and Shinkfield, 2007). Hansen (2005) distinguished more models of evaluations that may also be relevant to classify meta-evaluations: Result models, Explanatory process models, System models, Economic models, Actor models and Program theory models.

Due to many possible types of meta-evaluation, the objective of this paper needs to be better clarified. The Multi-view SDI assessment framework is still in a process of development. The meta-evaluation described in this paper can therefore be classified as a proactive or formative type because it is conducted during the framework development and aims at improving it. For the purpose of this paper the authors conducted also a pilot application of the framework (see for details in the Methodology section). The pilot application of the framework should be treated as a part of the process of its development. It has to be stressed that the pilot application differs from the potential real application of the framework. The purpose of the pilot application was only to evaluate the framework itself. Therefore the meta-evaluation of the framework might also be associated with the Hansen's explanatory process model which focuses on the nature of the application process of the object being evaluated.

Once the pilot application of the framework has been done it is also possible to evaluate the usefulness of the results of this pilot application. Therefore the focus of this paper is also on user's assessment of the framework's applicability to assess SDI. In that sense this meta-evaluation can be associated with the Hansen's Actor model which focuses on the stakeholders criteria for the assessment.

## 4.4 Methodology

Figure 4.2 presents the methodology to evaluate the Multi-view SDI assessment framework.

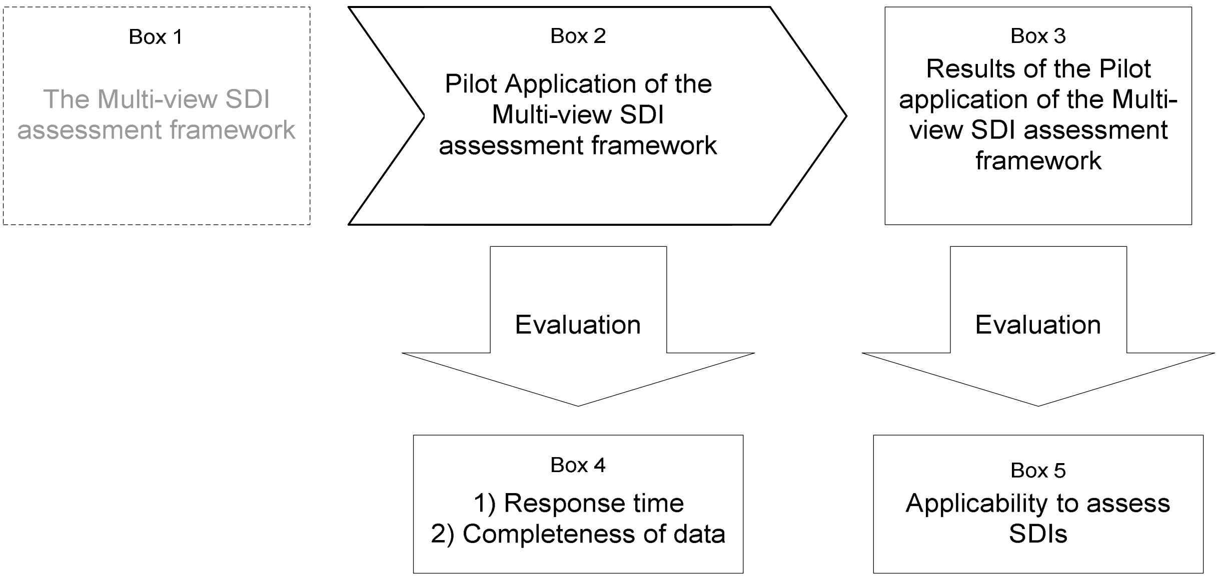


Figure 4.2 Methodology to evaluate the Multi-view SDI assessment framework

The Multi-view SDI assessment framework (Box 1 in Figure 4.2) was the object of evaluation. In order to evaluate the application process and applicability of the framework the authors conducted a pilot application of the framework (Box 2). The pilot application was the basis for evaluating the application process against the criteria listed in Box 4. The results of the pilot application (Box 4) were the basis for evaluating the applicability of the framework to assess SDIs (Box 5). The detailed methodology to conduct pilot application (Box 2), to evaluate the response time and completeness of data (Box 4) and to evaluate the applicability of the framework to assess SDIs (Box 5) is described below.

*Pilot application of the Multi-view SDI assessment framework (Box 2)*

In the first step the authors selected from the Multi-view SDI assessment framework those assessment approaches that could be fully applied i.e. their indicators had already been tested in previous studies. Four assessment approaches met this criterion of applicability. The first, the Clearinghouse suitability approach (Crompvoets & Bregt, 2008) assesses the status of the existing national spatial data clearinghouses around the world. It focuses on the systematic description of 15 clearinghouse characteristics. The second, the SDI-readiness approach (Delgado Fernández et al., 2005) aims to measure the degree to which a country is prepared to deliver its geographical information to the community. The third, the INSPIRE State of Play approach (Vandenbroucke et al., 2008b) is an adapted version of an approach to assess the status of NSDIs in Europe (SADL, 2005). The approach was adapted so that it can be applied no only in an European but also in an international context. This assessment approach is based on a number of SDI issues such as: organizational, legal, economical, spatial data, metadata, access to data and services, standards and thematic environmental data. The fourth, the Organizational approach (Kok & Van Loenen, 2005), identifies, describes and compares the current status of the organizational aspects of NSDIs. This assessment approach is based on the following organizational components: leadership, vision, communication channels and self-organizing ability of the sector.

In the next step the authors selected SDIs where the framework was applied. The authors decided to focus on National SDIs for several reasons. National SDIs are easily identifiable due to the existence of a national vision, strategy and steering committees of these SDIs. Most countries have also a spatial data clearinghouse at national level (Crompvoets, 2006 ). In addition National SDIs are considered to be the key level of SDIs hierarchy because they have full impact and relationship on the other levels of the SDI hierarchy through its components (Rajabifard et al., 2003a). Moreover, from practical reasons of conducting evaluation the authors could easily identify and contact National SDI coordinators and obtain the required data.

Based on the established network of contacts the authors contacted 21 NSDI coordinators of the following countries: Argentina, Brazil, Canada, Chile, Colombia, Cuba, Denmark, Ecuador, Guyana, Jamaica, Malaysia, Mexico, Nepal, the Netherlands, Norway, Poland, Serbia, Spain, Sweden, Turkey, Uruguay. NSDI coordinators were considered to be the most appropriate persons to contact for the following reasons: their perceptions can be treated as a sensitive indicators for changes in SDI (Crompvoets et al., 2007), they have the broadest and most complete knowledge about the NSDIs of their countries, and they act on behalf of an authorized NSDI institution. In addition, the information that they provide can potentially be treated as an official statement of the authorities about NSDI. The NSDI coordinators were contacted by e-mail.

The following step was to measure the indicators of the four selected assessment approaches. In order to measure the indicators' values we used 3 different methods: web survey, questionnaire, and statistical data. For the Clearinghouse approach all needed indicators values could be obtained by surveying the websites (web survey method) of the Clearinghouses. The web survey method is relatively easy and quick because of the easy access to the clearinghouse sites (Crompvoets et al., 2004). For collecting data for SDI-readiness, Organizational and INSPIRE State of Play approaches we used an interviewer absent questionnaire i.e. a questionnaire which is left with the respondent and picked up by the researcher when it is ready (Bernard, 2006). The reason for using this type of questionnaire was the relative easiness of obtaining data by one researcher from a number of respondents at relatively low cost. The questionnaire was sent to coordinators of the 21 National SDIs. The questionnaire consisted of three parts, each relating to one approach i.e. SDI-Readiness, INSPIRE State of Play, and Organizational. The questionnaire used fixed-choice or open ended types of questions. Finally, three indicators of the SDI-readiness approach, i.e. Human capital index, Web measure index and Infrastructure index, were measured based on statistical data from United Nations e-Government Survey 2008 (United Nations, 2008).

*Evaluating the response time and completeness of data (Box 4)*

Two potential challenges of applying the multi-method approaches were evaluated: the challenge of time and the challenge of data availability for the assessment approaches.

The strength of this framework lays in the simultaneous use of several assessment approaches which is supposed to generate more realistic assessment results than when the approaches are sequentially applied. Each approach might use different methods to obtain data. The time needed to obtain data for each assessment approach may vary depending on the method. The challenge of time has already been mentioned in a paper of Grus et al. (2007) as a potential obstacle and difficulty when applying the Multi-view SDI assessment framework. Therefore, evaluating the response time needed to obtain data for different assessment approaches is crucial to judge if different assessment approaches can be applied simultaneously and how much time is needed for each of them to provide the assessment data. In addition, the timeframe of evaluating complex and dynamic phenomena such as SDI should not be too long because the values of these dynamic and complex phenomena may change fast (Eoyang & Berkas, 1998). Therefore, the evaluation of SDI should be adjusted to this dynamic behaviour by measuring all indicators at the shortest time. For example, the monitoring of INSPIRE directive implementation and use requires yearly measurements of the indicators (European Commission, 2009).

Assessing complex phenomena (such as SDIs [see Grus et al., 2010]) can only be approached with complex resources (Cillers, 1998). This implies that assessing SDIs requires many assessment data to be collected. These data may be of very different types and from different sources. For some assessment approaches data might be easily available and for other approaches not. Therefore data availability might be an obstacle for efficient application of the framework.

In order to evaluate these two challenges the authors formulated two indicators:

1) NSDI coordinator response time - the time difference between the date when the request to provide indicators values was sent to NSDI coordinators and the date when the indicators values were received.

2) Completeness of data – the number of indicators without value.

*Evaluating the applicability of the Multi-view SDI assessment framework to assess SDIs (Box 5)*

Evaluation of the applicability of the Multi-view SDI assessment framework is based on the pilot application. The authors used the results of the pilot application to write NSDI assessment summary report (see Appendix 3) for each measured NSDI. In order to evaluate the applicability of the framework, the 21 National SDIs coordinators, the same who earlier provided the assessment data for their NSDIs, were asked to have a look to the summary report and consecutively fill in the questionnaire (see Appendix 2). The coordinators were explicitly asked to evaluate the applicability of the framework. They were also informed to treat the summary report only as an indication of the status of their NSDIs.

The statements in the questionnaire reflected two groups of criteria. The first group was derived from the claims about the strengths of the framework. These claims can be summarized in the following statement: 'by using the Multi-view SDI assessment framework the more objective, complete, bias-free and realistic SDI assessment can be obtained. The diversity of data obtained by applying multiple assessment approaches reflects the complexity of SDI and allows for indicating those SDI aspects, which lack behind the others' (Grus et al., 2007). The first four questions of the questionnaire related to these claims.

The second group of criteria was derived from the meta-evaluation criteria standard for conducting evaluations (Stufflebeam, 1974; The Joint Committee, 1994). This standard contains ten questions asking about technical adequacy, utility and efficiency of assessment frameworks (see Appendix 4). Out of ten questions the authors used four due to the following reasons. Two questions, one about the validity and biasness and another one about the objectivity of the assessment framework have already been covered by the questions related to the framework claims. The questions about the internal validity and scope of the assessment could not be answered because the framework's pilot application had no specific assessment purpose or scope. The questions about the relevance and pervasiveness of the findings to the intended audiences could not be answered because the pilot application had no SDI assessment audience specified.

## 4.5 Results and Discussion

Table 4.1 presents the results of the Multi-view SDI assessment framework pilot application to assess 21 National SDIs. The results presented in Table 4.1 correspond with Box 3 in Figure 4.2.

Table 4.1 The Results of the Multi-view SDI assessment framework application in 21 countries.

| NSDIs | Assessment approaches results | | | |
|---|---|---|---|---|
| | Clearinghouse suitability | SDI Readiness | INSPIRE State of Play | Organizational |
| Argentina | 43 | 53 | 52 | 50 |
| Brazil* | 38 | 56 | 50 | 75 |
| Canada* | 100 | 63 | 74 | 100 |
| Chile* | 50 | 58 | 50 | 75 |
| Colombia | 76 | 67 | 76 | 100 |
| Cuba | 60 | 53 | 59 | 75 |
| Denmark | 38 | 65 | 59 | 75 |
| Ecuador* | 34 | 44 | 59 | 75 |
| Guyana* | 0 | 41 | 27 | 50 |
| Jamaica* | 46 | 58 | 65 | 100 |
| Malaysia* | 67 | 39 | 44 | 50 |
| Mexico* | 75 | 58 | 73 | 75 |
| Nepal* | 49 | 32 | 55 | 50 |
| Netherlands | 79 | 59 | 59 | 75 |
| Norway | 77 | 67 | 76 | 75 |
| Poland | 36 | 49 | 39 | 50 |
| Serbia* | 0 | 45 | 55 | 50 |
| Spain | 100 | 72 | 71 | 75 |
| Sweden* | 50 | 64 | 55 | 100 |
| Turkey* | 0 | 37 | 32 | 50 |
| Uruguay* | 52 | 55 | 52 | 50 |
| * NSDI measurement results contained missing data | | | | |

The columns show the assessment values of each NSDI using the four assessment approaches. It is important to mention that for the purpose of this study we translate the 4 stages of the Organizational approach into percentage values. The scores of 25%, 50%, 75% and 100% indicate respectively the following stages: stand-alone, exchange, intermediary and network. However, for the real application of the framework this conversion might be too simplistic. The countries are sorted alphabetically.

The results are shown to demonstrate that the Multi-view framework could be applied to assess 21 National SDI using four different assessment approaches i.e. Clearinghouse suitability, SDI Readiness, INSPIRE State of Play and Organizational. The presented results can only be treated as an illustration of the framework application. The further discussion and analysis the assessment values of Table 4.1 is beyond the scope of this paper.

The following sub-sections discuss the results of evaluating the Multi-view SDI assessment framework The first sub-section discusses the results of evaluating the application process of the Multi-view SDI assessment framework. The second sub-section discusses the results of evaluating the applicability of the Multi-view SDI assessment framework.

### 4.5.1 Evaluating the application process of the Multi-view SDI assessment framework

The results described and discussed in this section refer to Box 4 in Figure 4.2.

*NSDI coordinators response time*

Table 4.2 shows the time that the National SDI coordinators needed to respond to the questionnaire. The mean response time was 51 days. This means that it is necessary to wait on average 51 days to receive a completed version of the questionnaire from the NSDI coordinator. In the case of Argentina the response time was considerably longer than for the response time of the other countries (205 days). On the contrary, in case of Serbia the response time was less than one day. Due to these outliers the median is a more robust parameter than the mean. The median for the presented sample equals to 38 days.

The response time presented in Table 4.2 refers only to the questionnaire method of assessment data collection. For the other data collection methods the time to collect the necessary data was much shorter. To collect statistical data for the 3 indicators of the SDI readiness assessment approach only several minutes were needed. To collect the values of 15 indicators of the Clearinghouse suitability approach using the web survey method, on average 30 minutes were needed to find out what the National Clearinghouse of the country was. Another 1.5 hour (on average) was needed to measure and classify 15 clearinghouse characteristics.

The results show that the time of the application process depends highly on the method used to measure indicators. The questionnaire method requires much more time to collect the needed assessment data in comparison with web survey method and collecting statistical data method. In some countries, it was observed that NSDI coordinators were very reluctant to provide any information via internet. In order to receive their response it was necessary to send several emails or to find a commonly known person who could be an intermediator between NSDI coordinator and the authors. In addition, on average two reminders about the questionnaire had to be sent to each NSDI coordinator.

Table 4.2 NSDI coordinators response time.

| NSDI | Sent | Received | Difference (days) |
|---|---|---|---|
| Argentina | 2007-10-12 | 2008-05-07 | 205 |
| Brazil | 2007-10-12 | 2007-12-10 | 58 |
| Canada | 2008-02-29 | 2008-04-30 | 60 |
| Chile | 2007-10-12 | 2007-12-10 | 58 |
| Colombia | 2007-10-12 | 2007-11-20 | 38 |
| Cuba | 2007-10-12 | 2007-12-21 | 69 |
| Denmark | 2007-10-18 | 2007-11-22 | 34 |
| Ecuador | 2007-10-12 | 2007-11-16 | 34 |
| Guyana | 2008-02-28 | 2008-04-07 | 39 |
| Jamaica | 2008-02-28 | 2008-05-14 | 76 |
| Malaysia | 2008-01-17 | 2008-02-21 | 34 |
| Mexico | 2007-10-12 | 2008-01-29 | 107 |
| Nepal | 2007-10-24 | 2007-11-25 | 31 |
| The Netherlands | 2008-01-22 | 2008-01-30 | 8 |
| Norway | 2007-10-18 | 2007-11-25 | 37 |
| Poland | 2008-03-03 | 2008-04-16 | 43 |
| Serbia | 2008-07-07 | 2008-07-07 | 0 |
| Spain | 2007-10-12 | 2007-11-19 | 37 |
| Sweden | 2008-05-14 | 2008-07-14 | 60 |
| Turkey | 2008-05-07 | 2008-05-16 | 9 |
| Uruguay | 2007-10-12 | 2007-11-16 | 34 |
| | | Mean | 51 days |
| | | Median | 38 days |

A mean of 51 (or median 38) days to assess 21 National SDIs can be regarded as a relatively long time to assess SDIs considering their dynamics. On the other hand the INSPIRE directive requires annual monitoring of SDIs. It seems than that the annual collection of the monitoring indicators is short enough period to capture all important changes within SDIs. Nevertheless, the time needed to collect the necessary assessment data should be reduced whenever possible. This can be done by substituting the questionnaire method of data collection with methods requiring less time to collect data. This is particularly important when large number of assessment approaches is applied simultaneously.

*Completeness of data*

Table 4.3 shows the numbers of missing data i.e. missing indicators or answers to the questionnaire, relating to each assessment approach. The table shows only these NSDIs for which at least one missing data was observed.

Table 4.3 The number of missing data per each assessment approach

| **NSDIs** | **The number of indicators or questions without value or answers** | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
| | Clearinghouse suitability (max 15 indicators) | SDI Readiness (max 12 questions) | INSPIRE State of Play (max 36 questions) | Organizational (max 9 questions) |
| Canada | 0 | 0 | 0 | 2 |
| Chile | 0 | 0 | 4(1)* | 0 |
| Mexico | 0 | 0 | 2 | 0 |
| Sweden | 0 | 4 | 2 | 0 |
| Jamaica | 0 | 0 | 1 | 1 |
| Ecuador | 0 | 0 | 2 | 0 |
| Malaysia | 0 | 0 | 3 | 0 |
| Uruguay | 0 | 0 | 2 | 0 |
| Nepal | 0 | 0 | 0 | 1 |
| Brazil | 0 | 0 | 9 | 0 |
| Serbia | 0 | 0 | 2 | 0 |
| Turkey | 0 | 0 | 2(1)* | 1 |
| Guyana | 0 | 0 | 11 | 0 |
| Sum | 0 | 4 | 40 | 5 |

* In case of INSPIRE State of Play the number of missing data could originate from indicating the answer 'Not sufficient information is available for assessing' or from the answers which was left empty. The numbers in brackets indicate missing data originating from answers which were left empty.

Regarding the Clearinghouse suitability assessment approach the indicators were measured by use of a with web survey. It appears that all the data were collected for this approach. The part of the questionnaire regarding the SDI readiness assessment approach contained 4 missing data. The missing data regarding this approach were recorded only for Swedish SDI. The part of the questionnaire regarding the INSPIRE state of play assessment approach contained 40 missing data. The missing data regarding this approach were recorded for 11 NSDIs. Finally the part of the questionnaire regarding Organizational approach contained 5 missing data. The missing data regarding this approach were recorded for 4 countries.

The results show that the application of the INSPIRE State of Play assessment approach results in relatively high number of questionnaires containing missing data. This approach contained an optional answer 'Not sufficient information is available for assessing'. The choice of this optional answer was treated as a missing data because it indicates that the information to answer the question or to provide the indicator value is missing. This might explain the high number of missing data for this approach. In addition the INSPIRE State of Play assessment approach, when compared with the three other approaches, contained the highest number of questions which increases the chances for missing data. Nevertheless, it has to be noted that only 2 out of 40 missing data in this approach were due unanswered questions. The remaining 38 missing values originated from indicating the option 'Not sufficient information is available for assessing'. Therefore in 38 cases the reason for the missing values was known. The three other assessment approaches i.e. Clearinghouse suitability, SDI-readiness and Organizational did not have an option like the one in the INSPIRE State of Play approach. In this case the NSDI coordinator, not having sufficient information to provide for assessment, had two options: 1) could not answer the question at all and leave it blank, or 2) give an answer based on their subjective judgement or choose the answer randomly. Moreover, it can be suspected that the respondents, not having an option to say that data are missing, are likely to indicate any answer not to leave the question blank. To conclude, it seems beneficial to have in a questionnaire and option such as 'Not sufficient information is available for assessing' because it increases the reliability of the answers (less random answers) and diminishes the chance that the respondents will leave the answer blank without a clear reason.

According to Kent (2001) the easiest way to deal with the incomplete dataset is to exclude the missing data from the dataset. However, this exclusion might not be useful if the sample is too small and the number of missing data too high. Another way is to present the records with the missing data but not use them in the further analysis. Other methods focus on estimating the missing values using statistical methods. The methods vary from simply replacing the missing values with the variable mean to more advanced methods such as regression (Frane, 1975). In Table 4.1 the authors chose to present all the results and indicate those containing the missing values with an asterix (*). Because the interpretation and analysis of the assessment results is beyond the scope of this paper the authors did not choose for any method to handle the missing data. In the calculation of the assessment values presented in Table 4.1 the missing data were given score 0. It has to be however stressed that in the practical application of the Multi-view SDI assessment framework the missing data should be treated as 'no value' and one of the methods described above should be used to handle the 'no value' result.

The results show that the completeness of assessment data might depend on the method used to collect them. In clearinghouse suitability approach, where all of data were collected by means of web survey, no missing data were recorded. The questionnaire method, in comparison with web survey method, resulted in a number of missing values. In the SDI Readiness assessment approach values for three indicators have been obtained from statistical data originating from United Nations e-Government Survey 2008 report. These statistical data were obtained for all sampled NSDIs.

#### 4.5.2 Evaluating the applicability of the Multi-view SDI assessment framework

The results described in this section correspond with Box 5 of Figure 4.2. Out of the 21 questionnaires sent to the NSDI coordinators we received 14 responses back. Figure 4.3 shows the results of the applicability evaluation of the Multi-view SDI assessment framework. The figure shows eight charts corresponding to the eight statements presented in the questionnaire.

The overall view on the results suggests a rather positive opinion of the respondents on the applicability of the Multi-view SDI assessment framework for assessing SDIs. The most frequent answer was 'Agree' (in 7 out of 8 statements).

The results confirm to a certain extent the claims that the use of the framework would provide an accurate, consistent, more complete, realistic and objective picture of SDI (Statements 1, 2 and 3). In addition, the respondents provided the strongest support for statement 4 saying that the Multi-view SDI assessment framework application allows indicating those NSDI aspects which need to be improved and enhanced. This strong support demonstrates that the Multi-view SDI framework design allows for determination the weakest aspects of SDI by looking from multiple views at the same time. The results also suggest that the framework can be applied to assess any other SDI (statement 7). This could mean that the framework is generic and its applicability is not limited only to National SDIs but can also be applied to assess e.g. the regional or local SDIs.

Concerning the cost-effectiveness of the Multi-view SDI assessment framework (statement 6), most of the respondents indicated answer 'Neutral'. A possible reason for this result could be that the respondents did not have enough knowledge to answer this question. Most probably it was difficult for them to estimate the cost-effectiveness of the framework application (statement 6) because they did not apply it themselves. Statement 8 was a 'control' statement to check the consistency of respondents' answers. The statement asked for the opinion if the assessment results are verifiable, which is similar with statement 3.

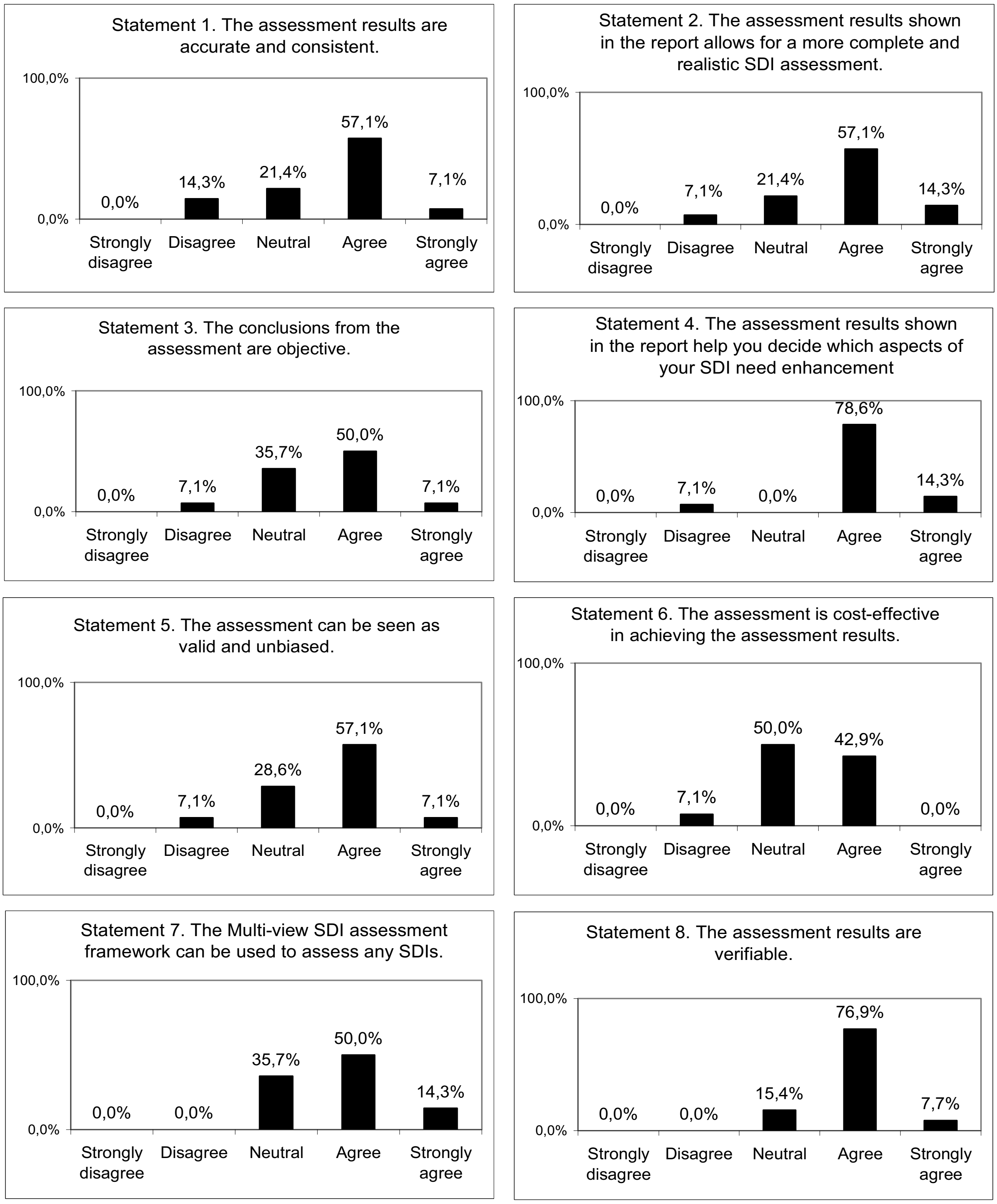


Figure 4.3 Evaluation results of the Multi-view SDI assessment framework.

The similarity of the answers to both statements indicates the consistency of the answers. The analyses of the responses show that only one respondent indicated for statement 3 the answer 'Disagree' while for statement 8 'Agree'. Therefore the results of the questionnaire could be treated as rather consistent.

## 4.6 Conclusions

The objective of this paper was to evaluate the Multi-view SDI assessment framework. The focus was on the evaluation of: 1) the application process of the framework and 2) the applicability of the framework to assess SDIs.

The results demonstrate that the Multi-view SDI assessment framework could be applied to assess National SDIs using four operational assessment approaches. NSDI assessment using more than one assessment approach gives an overview of NSDI performance from multiple viewpoints. This multi-view assessment can assist e.g. SDI coordinators to identify the status of many SDI aspects and help them to decide where to allocate resources to enhance their SDIs. In addition, it was possible to apply the framework at the same time in 21 different NSDIs which gives a good basis for cross national NSDI assessment, comparison and benchmarking of NSDIs.

Two aspects of the framework's application process were also evaluated: 1) the response time, and 2) completeness of data needed for assessment. The results show that the time needed for Multi-view SDI assessment framework application vary significantly between the measurement methods. Whenever possible it is recommended to use data collection methods which require less time. This might shorten the SDI assessment process significantly which is of particular importance when assessing complex and dynamic phenomena such as SDIs. The analysis of the completeness of the data show that a significant part of the measurements contained missing values. To be able to process the data, a decision needs to be made on the method for handling these missing values.

It has to be noted that the framework application heavily relies on responses provided by SDI coordinators. However, SDI coordinators might be biased to provide politically correct answers, not necessarily reflecting the true status of their SDI. For the future application of the framework two recommendations are made. First, more than one respondent with proven knowledge about assessed SDI should also be asked to provide data. Second, more assessment approaches that rely on e.g. statistical data, official reports, web surveys should be included in the Multi-view SDI assessment framework.

The evaluation of the Multi-view SDI assessment framework described in this article has been classified as proactive (formative), explanatory process model and actor model (concentrating on stakeholders). It has to be stressed that also other types of evaluations are necessary to fully evaluate the potential of the framework. For example, once the framework is applied it could be evaluated if the assessment results meet the specific user's requirements (actor model concentrating on clients). In addition economic models may be used to measure the costs and profitability of the framework. For instance, Hansen's (2005) evaluation model checking the framework's productivity, effectiveness and utility is an interesting option for further research.

*Acknowledgements*

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# Chapter 5

# An assessment view to evaluate whether Spatial Data Infrastructures meet their goals

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# 5 An assessment view to evaluate whether Spatial Data Infrastructures meet their goals

## 5.1 Introduction

Since the beginning of the nineties many local governments, countries, and regions have been building Spatial Data Infrastructures (SDIs) (Onsrud, 1998; 2007; Masser, 1999; 2005a; 2007; Rajabifard, 2002; 2003b, Crompvoets & Bregt, 2007). SDIs aim to facilitate the exchange and sharing of spatial data between stakeholders in the spatial data community (Crompvoets et al. 2008a). SDI is also about coordinating spatial data assets. Establishment and management of SDIs is in many cases coordinated by either mapping agencies, political or administrative organizations. These organizations integrate standards, data access facilities, policy and technology to enable spatial data exchange and sharing within SDI. The proponents of SDIs articulate many dimensions of goals and benefits which SDIs can realize and bring to the society, e.g: economical (e.g. reduced costs of data production), technical (e.g. improved development of applications), social (e.g. better management and decision making) and environmental (e.g. integration of spatial information and knowledge from different sectors for solving environmental issues). SDIs have also the potential to spatially enable governments by providing better service to decision-makers, politicians and societies (Masser, 2007; Masser et al., 2007; Rajabifard, 2003b; Rajabifard, 2007). SDI goals can also be more specific. The SDI policies written for a specific jurisdiction (e.g. province, country or region) define specifically what the designed and developed SDI aims to achieve. For example, the specific goal of the INSPIRE directive is to create an SDI that would assist policy-makers in their activities impacting the environment (European Commission, 2007). Given this wide array of intended but rarely proved SDI benefits and goals it is natural that policy makers, government representatives and public would be interested in the assessment studies measuring SDI benefits and the level of the goals realization.

The Dutch SDI implementation provides an example of a governmental demand for monitoring SDI goals. Since 2008 the Dutch SDI is being realized by implementing the vision and strategy plan called GIDEON (VROM, 2008). GIDEON sets up 4 goals that need to be realized by 2011. In 2009, the Ministry of Housing, Spatial Planning and the Environment (VROM), which is responsible for GIDEON implementation, requested a monitoring of the extent to which the 4 GIDEON goals have been realized. However, the 'ready-to-use' approach to monitor the realization of SDI goals which could also be applied to monitor GIDEON goals realization does not exist.

An extensive body of SDI assessment literature already exists. Many SDI assessment views have already been proposed (Onsrud, 1998; Masser, 1999; Kok & van Loenen, 2005; Delgado et al., 2005; SADL, 2005; Rodriguez Pabón, 2005, Georgiadou et al., 2006; Lance et al., 2006; Crompvoets et al., 2008a). The majority of them have been proposed by the SDI scientific community. The character of these studies was rather intuitive and curiosity driven. Their aim was to explore and build knowledge about SDI performance and benefits. These studies were natural in the early stage of SDI development when the knowledge about SDI was limited. However, in the recent years a shift from an intuitive to more rational SDI assessments can be observed (Bregt et al., 2008). The increasing demanded for rational assessments requires generic assessment views and approaches that measure e.g. the extent to which SDIs programs meet their objectives. (Lance et al., 2006; 2009). There is also a growing awareness across governments and communities of practitioners that much more attention needs to be paid to assessing the social and economic impacts of SDIs. These impacts need to be articulated when a significant number of such infrastructures have already been established (Craglia & Nowak, 2006). Till now SDI impact studies had mainly an ex-ante character i.e. focused on predicted SDI impacts and benefits (Cragila et al., 2008; Cragila, 2003; Dufourmont, 2004). Ex-post impacts studies seldom have been done (Lance et al., 2006). As a response to the growing need for SDI assessment a Multi-view SDI assessment framework has been proposed (Grus et al., 2007; Crompvoets et al., 2008a). This framework collects the existing SDI assessment approaches and classifies them in terms of 1) different assessment views e.g. organizational, technical, etc. and 2) different assessment purposes i.e. knowledge, development and accountability. The Multi-view SDI assessment framework can provide a comprehensive assessment of SDIs and provide some directions for further development (Grus et al., 2008). However, in the light of a growing attention for a more rational SDI assessment, the existing array of SDI assessment views will not help SDI practitioners in the assessment of the extent to which specific SDI goals are being met. Therefore there is a need to extend the Multi-view SDI assessment framework with an assessment view that focuses on measuring specific SDI goals realization.

In this paper the authors develop and present a generic assessment view to assess the extent to which SDIs realize their goals. The view is implemented in the Dutch SDI and evaluated by the potential users.

The article is structured as follows: Section 2 presents the methodology used to develop the assessment view. Section 3 presents the developed SDI goal oriented assessment view. Section 4 discusses the view implementation in the Dutch case study. Section 5 presents and discusses the results of users' evaluation of the developed assessment view. Section 6 closes the paper with conclusions and recommendations for the further research.

## 5.2 Methodology

To develop a SDI goal oriented assessment view the authors firstly reviewed the existing evaluation models. Hansen (2005) presented a typology and classification of several evaluation models. They differ in the questions that they aim to answer and evaluation criteria they use (see Table 5.1). Based on the analysis of the models, the authors of this article decided that the 'goal-attainment model' model fits best the objective of developing a goal-oriented SDI assessment view. The 'goal-attainment model' falls into a broader category of 'result models' which focus on the results of a program or organization. In the 'goal-attainment model' the results are assessed only in relation to the predetermined goals. The evaluation criteria should be derived from these goals. The 'goal-attainment model' does not provide a ready-to-use assessment view to assess SDI goals realization. It is rather a concept that can drive the further development of a goal oriented evaluation. Therefore the authors chose this model as a conceptual foundation for the development of a SDI goal oriented assessment view.

To develop a SDI goal-oriented assessment view the authors used the Multi-view SDI assessment framework (Grus et al., 2007; Crompvoets et al., 2008a) (see Figure 5.1). The Multi-view SDI assessment framework consists of multiple views on SDI assessment. Each view is applied or can be developed in four phases according to which the new goal-oriented assessment view will also be developed: Phase 1) assessment purpose, Phase 2) assessment approach, Phase 3) application, Phase 4) evaluation.

Table 5.1 Classification of the evaluation models (Hansen, 2005)

| *Evaluation Models* | *Questions* | *Criteria for Evaluation* |
|---|---|---|
| *Result models* | | |
| a) Goal-attainment model | a) To what degree has the goal(s) been realized? | a) Derived from goal(s) |
| b) Effects model | b) Which effects can be uncovered? | b) Open, all consequences should be uncovered |
| *Explanatory process models* | Is the level of activity satisfactory? Are there implementation problems? | Performance is analyzed from idea to decision and implementation and to the reaction of the addressees |
| *System model* | How has performance functioned as a whole? | Realized input, process, structure and outcome assessed either in relation to objectives in same dimensions or comparatively |
| *Economic model* | | |
| a) Cost-efficiency | a) Is productivity satisfactory? | a) Output measured in relation to expenses |
| b) Cost-effectiveness | b) Is effectiveness satisfactory? | b) Effect measured in relation to expenses |
| c) Cost-benefit | c) Is utility satisfactory? | c) Utility measured in relation to expenses |
| *Actor model* | | |
| a) Client-oriented model | a) Are clients satisfied? | a) Formulated by clients |
| b) Stakeholder model | b) Are stakeholders satisfied? | b) Formulated by stakeholders |
| c) Peer review model | c) Is professional quality in order? | c) Formulated by peers |
| *Programme theory model* (theory-based evaluation) | What works for whom in which context? Is it possible to ascertain errors in program theory? | Program theory is reconstructed and assessed via empirical analysis. |

The first phase concentrates on determining one of the three purposes of assessing SDIs: 1) accountability; 2) knowledge; 3) development (Chelimsky, 1997; Grus et al, 2007). The second phase focuses on developing an assessment approach. By an assessment approach the authors understand the whole assessment methodology of assessing SDI from a particular viewpoint (Grus et al., 2007) e.g. data access, organization, goals realization, etc. The third phase concentrates on the application of the assessment approach. The main activity in this phase is collecting necessary assessment data and measuring the values of indicators. The fourth phase concentrates on interpreting indicators' values. In this phase the merit of a particular SDI is judged. The merit is evaluated based on the indicators values and their relation to e.g. target values. The result of this phase should provide an evaluation of SDI from a specific view.

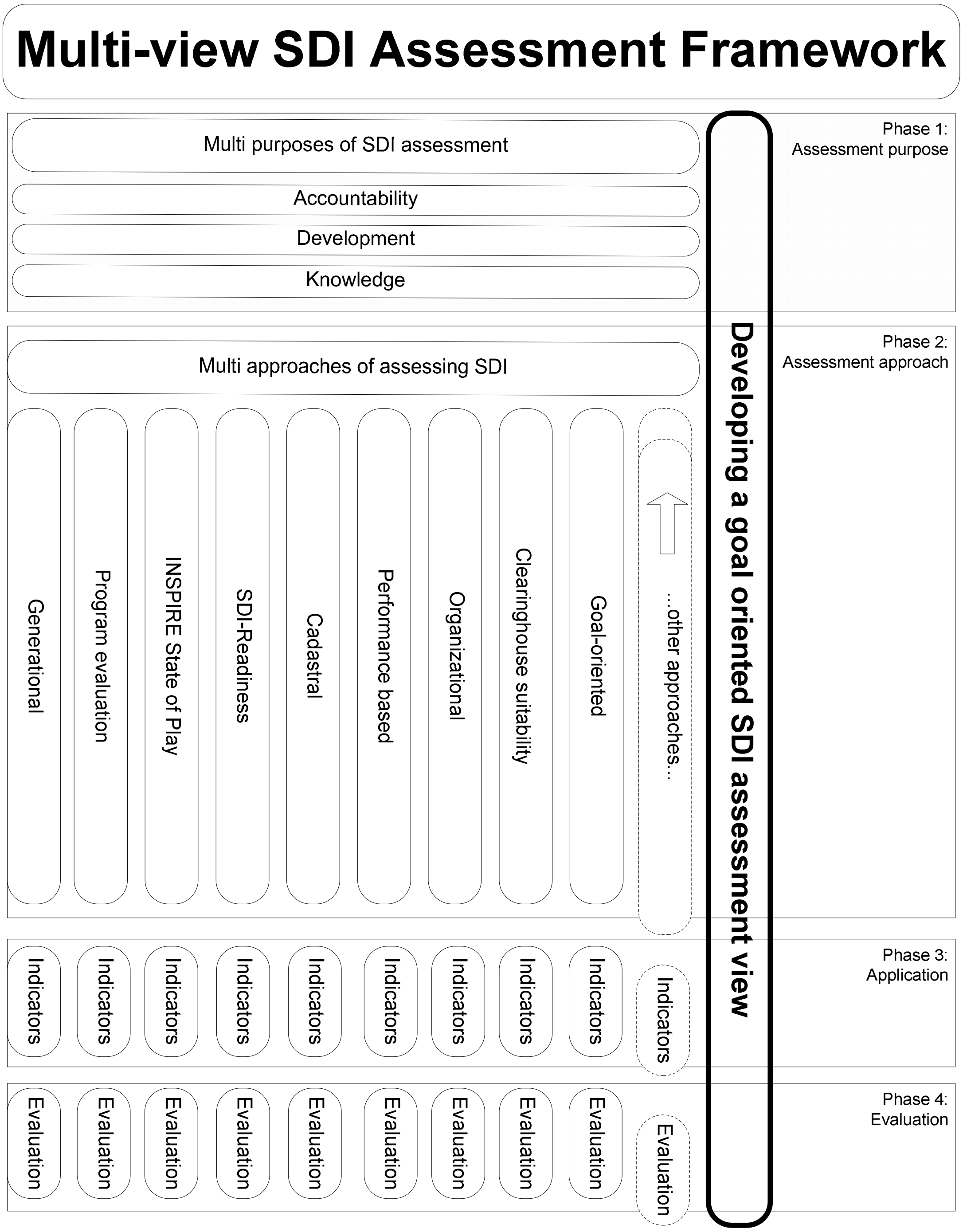


Figure 5.1 The Multi-view SDI assessment framework

## 5.3 A goal oriented assessment view

Figure 5.2 presents a schematic picture of the proposed assessment view for assessing the extent to which SDI realizes its goals. The view is divided into 4 phases, according to which it is developed.

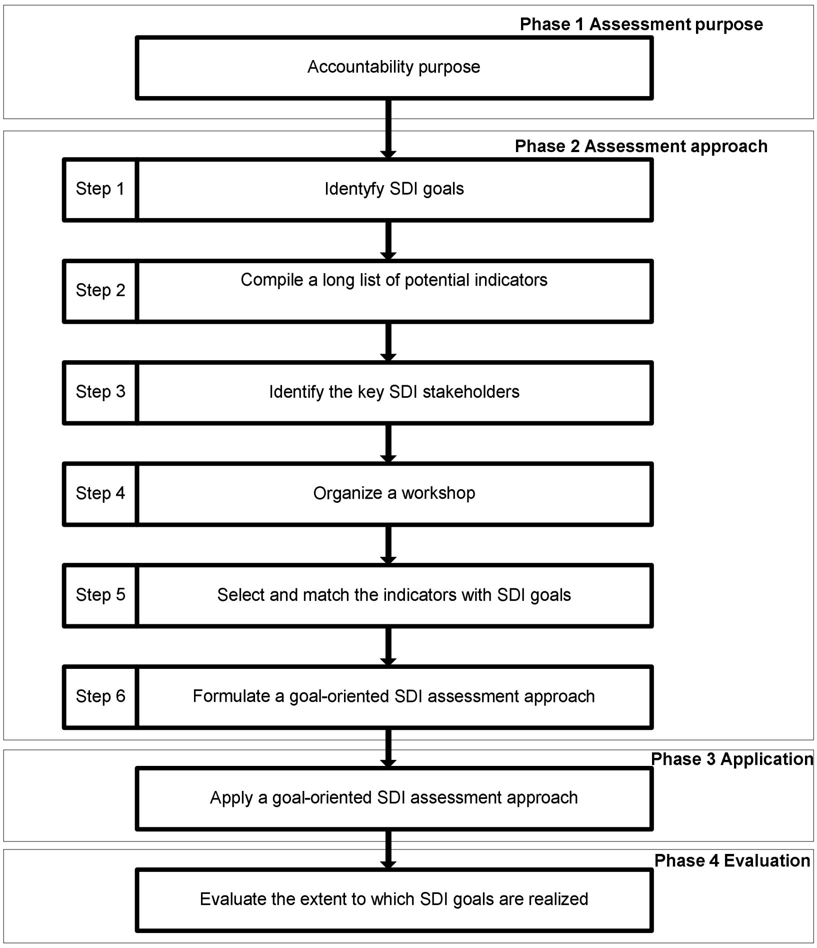


Figure 5.2 A goal oriented SDI assessment view.

Phase 1 focuses on specifying the assessment purpose. According to Hansen (2005) the purpose of 'goal-attainment model' is to answer the question: to what degree has the goals been realized? This assessment purpose can be classified as accountability (Chelimsky, 1997; Grus et al, 2007).

Phase 2 focuses on developing the assessment approach and consists of 6 steps. The aim of an assessment approach is to derive the assessment criteria and indicators from the SDI goals (see Table 5.1 – 'goal-attainment model').

Step 1: Identify SDI goals.

Step 2: Compile the long list of potential indicators.

Step 3: Identify the key SDI stakeholders.

Step 4: Organize a workshop where the stakeholders will discuss, work on and propose their own ideas for a goal oriented SDI assessment approach.

Step 5: Select from the long list those indicators that potentially can best measure the realization of each SDI goal. The SDI stakeholders participating in the workshop should be asked to select the indicators. Additionally, the stakeholders can also propose their own indicators which are not in the long list.

Step 6: Formulate a goal-oriented SDI assessment approach. This step focuses on making the selected indicators operational. The indicators selected from the long list by the workshop participants (Phase 2 Step 4) indicate only the general direction of what should be measured. To make the indicators operational they have to be adjusted. A group of SDI experts, preferably the representatives of the workshop stakeholders and experts in the field of assessment should review and assess each indicator. The assessment of the indicators can be done against the criteria in Table 5.2. The criteria are partly derived from the characteristics of SMART indicators (WHO, 2000) and adjusted to the needs of SDI goal monitoring.

Table 5.2 Criteria for assessing indicators

| Criterion | Description |
|---|---|
| Measurability | determines if it is practically possible to measure the value of the indicator |
| Measurement methods | determines the methods and data sources to measure the value of the indicators |
| Scale | determines the units and scale of the value of the indicator |
| Representativeness | determines how the indicator value corresponds to the measured characteristic |
| Target value | determines the maximum value the indicator may have |

Phase 3 focuses on the application of the approach. The application process concentrates on measuring the assessment indicators using the methods defined in the previous phase

Phase 4 focuses on interpreting the meaning of the indicators values measured in the previous phase. The indicators values should be evaluated against the criteria of merit defined for the goal oriented SDI assessment view. The main criterion of the developed and applied approach is the extent to which SDI goals has or has not been realized. The interpretation of the indicators values should allow judgment on this main criterion.

## 5.4 Case study

To demonstrate how the developed view is implemented in a real world case it was applied to measure the extent to which the goals of the Dutch Spatial Data Infrastructure (GIDEON) are realized. This section is divided into two parts. First part describes the GIDEON – strategy approach and plan to develop Dutch SDI. Second part discusses the implementation of the developed view in a GIDEON case.

### 5.4.1 GIDEON as a case study

*GIDEON approach and implementation strategy*

In 2008, the Dutch government approved GIDEON as a policy aiming at the implementation of the National Spatial Data Infrastructure (NSDI) in the Netherlands. The document has been developed in close cooperation with the stakeholders and aims at developing a key geo-information facility for the Netherlands that all parties in the Dutch society will use. The execution of GIDEON should take place by pursuing seven implementation strategies which lead to the achievement of the GIDEON goals (see 4.2). Various parties are working together on the realization of the implementation strategies that will lead to the creation of a key geo-facility for The Netherlands. GIDEON also expresses the need to monitor the progress of implementing its strategies and realization of its goals.

*Implementation a managerial set-up of GIDEON*

At the beginning of 2008 the policy document has been accepted by the geo-information council and national council for e-government services, which act as advisory boards for the Ministry of VROM and Minister of Interior respectively. The administrative responsibility and coordination for geo-information policy has been given to the Ministry of VROM, which adopted the document, and subsequently it was also approached by the Dutch parliament. In the middle of 2008 the implementation started under the responsibility of the Ministry of VROM. The GI council is acting as steering committee for the implementation of GIDEON. The GI council has representatives of all important governmental SDI stakeholders and in its role as steering committee it creates conditions for GIDEON implementation and monitors progress and consistency in its implementation. Geonovum is the SDI coordination body and is supporting VROM in its coordination role by monitoring the progress of GIDEON and reporting to the GI-Council.

One of the first steps in the GIDEON implementation process has been to implement the plans in more detail to provide a clear picture on the milestones of the implementation strategies and their interrelationship. Roadmaps have been designed which form the basis for a half-yearly reporting to the GI-council about the status of the different milestones. However, these reports inform the GI-council only about the status and progress of the predefined milestones of the seven implementation strategies. It is not measured to what extend the four GIDEON goals are realized. Therefore the Ministry of VROM expressed the need to also monitor the goals realization of GIDEON.

**5.4.2 Implementing a goal-oriented SDI assessment view in GIDEON**

The request of the Ministry of VROM forms an appropriate test case to apply the developed goal-oriented assessment view. The text below describes the process of the goal-oriented assessment view implementation. The assessment view has been applied following the 4 phases of the Multi-view SDI assessment framework.

Phase 1 – Assessment purpose: The Ministry of VROM searched for an answer to the question: to what degree have the GIDEON goals been realized? This assessment could be classified as an accountability purpose because it explicitly asked about the results of SDI implementation.

Phase 2 – Assessment approach: This phase focused on formulating an assessment approach to measure the GIDEON goals realization. The process of formulating the approach followed the 6 steps.

In the 1st step the GIDEON goals were identified. The GIDEON document (VROM, 2008) explicitly identifies 4 goals to be realized within four years from the GIDEON policy implementation. The goals are:

- the public and businesses will be able to retrieve and use all relevant geo-information about any location;
- businesses will be able to add economic value to all relevant government-provided geo-information;

- the government will use the information available for each location in its work processes and services;
- the government, businesses, universities and knowledge institutes will collaborate closely on the continuing development and enhancement of the key facility.

In the 2nd step a long list of potential indicators has been compiled. As a base for collecting the potential indicators the authors used indicators from four assessment approaches of the Multi-view SDI assessment framework (Grus et al., 2007): Clearinghouse suitability, SDI-readiness, INSPIRE State of Play and Organizational approach. These four assessment approaches were chosen because they were fully operational i.e. their indicators could be measured and had been applied before. The authors compiled a list consisting of 72 potential indicators. (See Appendix 5 for the list of potential indicators). The order of the indicators in the list was random.

In the 3rd step the key Dutch SDI stakeholders have been identified. 21 organizations which representatives were involved in creating GIDEON are listed in the policy document (see VROM, 2008 p. 3). The authors treated this list as a complete record of the stakeholders involved in creating the Dutch SDI.

In the 4th step on 22nd October 2008 a one-day workshop 'Monitoring GIDEON' was held at the Wageningen University in the Netherlands. The objective of the workshop was to develop an approach for goal-oriented SDI assessment using GIDEON as a case study. In total, 23 representatives of 21 organizations listed in the GIDEON document as the stakeholders were invited to the workshop.

In the 5th step the indicators were selected and matched with the GIDEON goals. The participants selected from the long list these indicators which, according to them, would best measure GIDEON goal realization. The participants were asked to select a maximum of five indicators per goal. Besides from selecting indicators from the long list, the workshop participants proposed also 18 new indicators. After the individual selection and proposition of the indicators, the workshop participants discussed their own indicators in 6 groups. Each participant was assigned to a group in a random way. During the group discussion the participants had an opportunity to communicate and defend their choice of indicators with other participants of the workshop. The objective of discussing the individual results in groups was to come to some level of consensus about the key indicators.

In the 6th step the final goal oriented SDI assessment approach was formulated. In the previous step 39 indicators (21 selected and 18 proposed) were identified as the candidate indicators. To finalize the approach each of those 39 indicators were assessed and analyzed. Two members of the Dutch SDI implementation executive body GIDEON and 2 members of the Centre for Geo-information, Wageningen University were involved in the assessment and analysis of the indicators. The members were well acquainted with the proposed assessment approach, evaluation theory and practice. Due to the request of the Dutch Ministry of VROM for a short and compact assessment report the number of 39 indicators was considered still too high. It was decided to select no more than 3 indicators per goal. The selection was based on 5 criteria from Table 5.2. Indicators that were selected by the majority of experts were considered to be the key indicators for monitoring the Dutch SDI goals realization (see Table 5.3).

Table 5.3 Final list of indicators for monitoring the Dutch SDI goals realization

| SDI goal | Indicator measuring goal realization |
|---|---|
| **Goal 1:** the public and businesses will be able to retrieve and use all relevant geo-information about any location. | **Indicator 1.1** The number of visitors of the Dutch national georegister (NGR). (Indicator source: Google analytics linked to National GeoRegister [NGR]). |
| | **Indicators 1.2** Availability of datasets and services (indicator source: NGR) |
| | **Indicator 1.3** The use of view and download services (Source: TNO, DINO) |
| **Goal 2:** businesses will be able to add economic value to all relevant government-provided geo-information | **Indicator 2.1** General governmental policy terms for (re)use of geographical information (indicator source: NGR). |
| | **Indicator 2.2** The percentage of datasets from GIDEON annex 1 that are available without any restrictions (Indicators source: NGR). |

Table 5.3 Contiuned

| | |
|---|---|
| | **Indicator 2.3** Yearly turnover of the geo-information business in the Netherlands (Indicator source: Geobusiness Nederland [see Bregt et al., 2009b]). |
| **Goal 3:** the government will use the information available for each location in its work processes and services | **Indicator 3.1** The level of cooperation within 5 chains of the GIDEON (Indicator source: see Geonovum ,2009). |
| | **Indicator 3.2** The use of geo information within e-government processes (Indicator source: http://monitor.overheid.nl). |
| **Goal 4:** the government, businesses, universities and knowledge institutes will collaborate closely on the continuing development and enhancement of the key facility. | **Indicator 4.1** The number of Geo-information events (Indicators source: www.geo-info.nl). |
| | **Indicator 4.2** The % of organizations with unfulfilled vacancies in geo-sector (Indicator source: Geobusiness Nederland [see Bregt et al., 2009b]). |
| | **Indicator 4.3** Expenditure of the private sector in the Netherlands on research and development of geo-information products and -services (Indicator source: Geobusiness Nederland [see Bregt et al., 2009b]). |
| | **Indicator 4.4** Value of the Dutch geo-information research sector. (Indicator source: Geobusiness Nederland [see Bregt et al., 2009b]). |

Phase 3 – Application: The developed approach was applied in the summer 2009. The indicators values were measured by an employee of a Geonovum who collected data from the sources specified for each indicator. On the basis of the collected data the indicators have been calculated. Table 5.4 presents the indicators' values.

Table 5.4 Value of indicators august 2009

| Indicator measuring goal realization | Indicator Value |
|---|---|
| **Goal 1: the public and businesses will be able to retrieve and use all relevant geo-information about any location** | |

Table 5.4 Continued

| | |
|---|---|
| **Indicator 1.1** The number of visitors of the Dutch national georegister (NGR) (http://www.nationaalgeoregister.nl) per day. | Total number of visitors per day: 55<br>Total number of unique visitors per day: 33<br>(Indicator source: Google analytics linked to NGR) |
| **Indicators 1.2.** Availability of datasets and services | 217 datasets available from GIDEON Annex 1.<br>From these 217 datasets:<br>• 83 have a view service<br>• 1 has a download service<br>From GIDEON Annex 1 INSPIRE datasets there are 8 out of 43 datasets available (indicator source: NGR) |
| **Indicator 1.3.** The use of view and download services | Not available (Source: TNO, DINO) |
| **Goal 2: businesses will be able to add economic value to all relevant government-provided geo-information** | |
| **Indicator 2.1** General governmental policy terms for (re)use of geographical information. | These general governmental policy terms of (re)use of geographical information are considered as maximal costs of distribution and no restrictive terms of use that may prevent the use of geographical information<br>• From 217 datasets 36 have costs information (17%)<br>• From these 36 datasets it is compulsory to pay for 20 (55%)<br>• From these 36 datasets 16 are gratis (44%)<br>(indicator source: NGR) |
| **Indicator 2.2** The percentage of datasets from GIDEON annex 1 that are available without any restrictions | From the 217 datasets 150 do not have any use restrictions, for 36 datasets it is not know what are the restrictions and 31 have use restriction.<br>150 out of 217= 69% from the available datasets have not use restrictions (Indicators source: NGR). |
| **Indicator 2.3** Yearly turnover of the geo-information business in the Netherlands. | 2007: 747 million euro<br>2008: 900 million euro<br>(Indicator source: Geobusiness Nederland [see Bregt et al., 2009b]) |
| **Goal 3: the government will use the information available for each location in its work processes and services** | |

Table 5.4 Continued

| | |
|---|---|
| **Indicator 3.1** The level of cooperation within 5 chains of the GIDEON. | 4 out of 9 milestones of the 5 chains of GIDEON have been achieved (44%) (Indicator source: see Geonovum ,2009) |
| **Indicator 3.2** The use of geo information within e-government processes | Municipalities: 26%<br>Provinces: 65%<br>Waterboards: 42%<br>(Indicator source: http://monitor.overheid.nl) |
| **Goal 4: the government, businesses, universities and knowledge institutes will collaborate closely on the continuing development and enhancement of the key facility.** | |
| **Indicator 4.1** The number of Geo-information events | 2009: 23<br>2008: 28<br>2007: 31<br>2006: 26<br>(Indicators source: www.geo-info.nl) |
| **Indicator 4.2** The % of private organizations with unfulfilled vacancies in geo-sector | **78%** of the private companies has unfulfilled vacancies (Indicator source: Geobusiness Nederland [see Bregt et al., 2009b]) |
| **Indicator 4.3** Expenditure of the private sector in the Netherlands on research and development of geo-information products and - services. | 2008: 56 million euro (Indicator source: Geobusiness Nederland [see Bregt et al., 2009b]) |
| **Indicator 4.4** Value of the Dutch geo-information research sector. | 45 million euro (=450 fte) (Indicator source: Geobusiness Nederland [see Bregt et al., 2009b]). |

Phase 4 – Evaluation: The indicators' values were presented to the participants of the workshop 'Evaluating the goals realization of the Dutch SDI' organized in October 2009 in Wageningen by Geonovum. The objective of the workshop was to evaluate and discuss the GIDEON goals realization. The workshop participants consisted of 20 representatives of 21 organizations participating in the Dutch SDI. The values of the indicators were visualized in several graphs to realize a thorough understanding of the meaning of the indicators' values. Three questions were raised to the participants: (1) Is the correct quantitative data acquired? (2) Are the proposed indicators representative enough to assess the GIDEON goal attainment assessment? (3) What is your opinion about the GIDEON implementation progress? The overall opinion of the workshop participants is that the determined indicator values are correct. However, some of these data are not entirely complete or the reliability of the data source is not optimal (yet). From the answers on the second question, the general conclusion could be drawn that the representativeness of approximately half of the selected indicators to assess GIDEON goal attainment is doubtful. In other words, some indicators per goal are not completely suitable for assessing the particular GIDEON goal in question. This is mainly due to the fact that the selected indicator values may not correctly reflect the GIDEON goals. Nevertheless, approximately half of the total number of indicators and their values were qualified as useful and effective. For example indicator 3.2 belonging to the 3rd goal of GIDEON, and the indicators belonging to the 4$^{th}$ Goal of GIDEON were regarded as such. In the discussion on the third question around 90% (19 participants) of the workshop participants agreed that the implementation of GIDEON is on the right track and are optimistic about the progress of goals realization. 10% (2 participants) had an opposite opinion.

### 5.4.3 Discussing the implementation of the goal-oriented SDI assessment view to GIDEON

The goal-oriented SDI assessment view was implemented in GIDEON according to the 4 phases of the Multi-view SDI assessment framework (see Figure 5.2). The results show that the assessment view could be applied to deliver a basis for the assessment of GIDEON goals realization.

As a basis for compiling a long list of indicators the authors selected 72 indicators from the four existing SDI assessment approaches. The stakeholders proposed also a large number of their own indicators which potentially were more accurate than the indicators used. However, the majority of these indicators were not attainable because they could not be measured or information about their values was not available. It should also be noted that for some selected indicators the exact target values could not be specified. However a growing value of indicator over a period of time was considered as a good result. In this case, it was decided that the series of measurements showing a trend gives much better base for interpreting indicators' values than the measurement taken at one point of time.

There are two potential reasons for regarding half of the selected indicators as unsuitable to measure GIDEON goals realization. Firstly, some indicators, which seemed to be very appropriate had to be removed from the final list because they did not conform to the criteria from Table 5.2 and could not be used. In turn, large numbers of stakeholders were reluctant to accept the indicators which were finally used. Secondly, the accuracy of SDI goals definition plays critical role in the process of indicators selection. This is because assessment indicators should precisely reflect the components of SDI goals. In case of GIDEON the selection of the indicators was hampered by the vagueness of the GIDEON goals definition which leaves room for interpretation. Consequently, the appropriateness of the final list of the indicators to measure GIDEON goals may still be questioned by others who interpret the meaning of GIDEON goals differently.

## 5.5 Evaluation of the goal-oriented assessment view

To evaluate the proposed assessment view the authors used the meta-evaluation standard criteria for evaluating assessment frameworks (Stufflebeam, 1974; Shepard, 1977; The Joint Committee, 1994). The evaluation standard comprises three groups of criteria: technical adequacy, utility, and efficiency (see Appendix 4). The evaluation has been conducted by asking the group of respondents to fill in a questionnaire containing meta-evaluation standard statements (see Appendix 6). The statements were formulated in such a way that the answers close or equal to 'fully agree' confirm the validity of the proposed assessment view to assess SDI goals realization. After each statement, the respondent could fill in personal comment on a given answer. The respondents were the participants of the workshop 'Evaluating the goals realization of the Dutch SDI' organized in October 2009 in Wageningen, the Netherlands. This group was considered as appropriate to evaluate the developed assessment view because they were particularly interested in assessing their SDI. They could also be considered as potential users of the goal-oriented assessment view.

A total of 12 participants of the workshop expressed their opinions to the statements of the evaluation. Figure 5.4 presents the responses for all of the statements of the questionnaire. For the majority of the statements (except for statement 5 and 6) the dominant percentage of respondents indicated answers to the right of the scale rather than to the left. This can be interpreted as a tendency to agree rather then disagree. The highest percentage of respondents agreed with the last statement about the cost-effectiveness of the assessment view. This means that according to the respondents the findings of the goal-oriented assessment view are worth more than the costs of obtaining the information.

The stronger tendency to indicate ‘disagree’ could be observed for two statements: the first about the relevance of the findings of the assessment to those interested in GIDEON goals monitoring (statement 5) and the second about the inclusion of all important and relevant indicators for assessing GIDEON goals (statement 6). These results suggest that the respondents were rather dissatisfied with the choice of the indicators for GIDEON goals monitoring. Thus they found the relevance of the assessment findings rather limited. The potential reasons for this dissatisfaction has been presented in section 4.3.

The comments written by the respondents to these statements suggest that the accuracy and consistency (statement 3) and objectivity of the assessment results (statement 4) are largely dependent on the choice of the appropriate indicators. For the implementation of the assessment view presented in this article the appropriateness of the indicators was assessed rather critically. This can explain a large percentage of the respondents disagreeing with statements 2, 3 and 4.

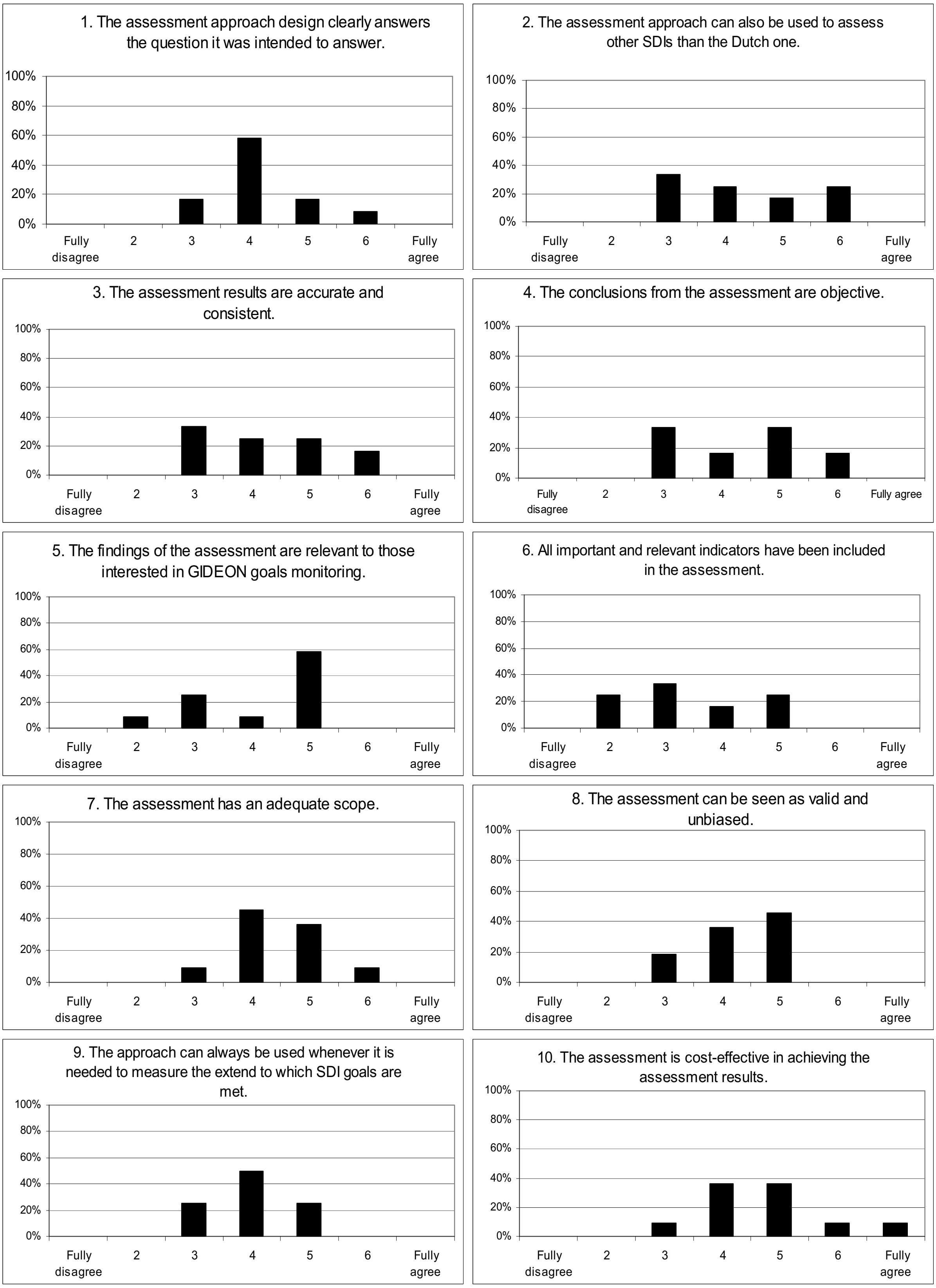


Figure 5.4 The respondents opinion about 10 statements evaluating the assessment view to assess SDI goals realization

## 5.6 Conclusions

The objective of this article was to develop a goal oriented assessment view for assessing SDI goals realization. The methodology was proposed to realize this objective. The proposed assessment view was developed according to the 4 phases of the Multi-view SDI assessment framework. As a result a SDI goal oriented assessment view has been proposed.

The practical applicability of the proposed assessment view has been demonstrated by its implementation in the Dutch SDI case. All the phases of the assessment view could be followed. However, the evaluation phase was hampered by the limited number of appropriate indicators. As a result, the stakeholder's evaluation of the extent to which SDI goals are being realized was based on a limited number of indicators. The assessment view was also evaluated by its potential users. The evaluation results indicate that the users agree with the proposed goal-oriented assessment view design and its applicability to assess how SDIs reach their goals. However, in the Dutch SDI case, the appropriateness of the final list of indicators was a matter of concern.

The results suggest that the precision with which SDI goals are defined substantially impact the reliability and relevance of the assessment results. Vagueness of the Dutch SDI goals definition leads to multiple interpretations of what exactly is going to be achieved by SDI. This in turn leads to the problem of selecting commonly agreed assessment indicators and evaluating the realization of SDI goals. It is recommended that before assessing SDI goals realization the goals should be defined clearly.

There are two general conditions for applying the presented view: 1) SDI goals have to be defined; 2) The SDI stakeholders have to be identifiable and approachable. The first condition assumes that in the SDI vision or strategy plan the commonly agreed SDI goals have clearly been defined. When the goals are clearly defined it is possible to identify the indicators that show the extent to which these goals are realized. Proper indicators relating to the SDI goals are at the foundation of the assessment view (Giff & Crompvoets, 2008). The second condition assumes the active involvement of the SDI stakeholders in the process of assessing the realization of SDI goals. This active involvement, especially in the process of selecting indicators, helps to build user's trust for the evaluator and confidence in the evaluation result.

The goal-oriented SDI assessment view extends the existing array of assessment views of the Multi-view SDI assessment framework. The SDI assessment views that have been proposed so far were rather intuitive, curiosity driven and had ex-ante nature. The presented goal-oriented SDI assessment approach complements the existing assessment views as it offers a more specific and rational assessment which helps to evaluate SDIs for accountability purposes. It is also developed as an ex-post assessment. The goal-oriented SDI assessment view extends the Multi-view SDI assessment framework not only by another assessment view but also by a newly developed set of operational indicators. This need for new indicators confirm the need for assessing SDIs in a multi-view way because each assessment view, in this case a goal-oriented view, requires specific indicators suited for specific assessment view and purpose. For a comprehensive SDI assessment it is necessary to have a wide array of indicators designed for the purposes and views to be involved in the assessment.

For further study it is recommended to implement the proposed assessment view to measure the goals realization of other infrastructures. The design of the assessment view is generic, so it can be used to measure the extent of goals realization of any infrastructures with clearly defined and commonly agreed goals and where all the stakeholders can be identified and approached.

In addition to measuring the intended SDI goals and benefits, also the unintended or unforeseen impacts and benefits of SDIs cannot be neglected. These unintended benefits and impacts may be equally interesting and important as the intended ones. Therefore in the future studies on SDI assessment it is recommended to develop assessment methods capable of capturing the unplanned SDI results.

*Acknowledgements*

We would like to acknowledge and thank the participants of two workshops on monitoring the GIDEON goals, held in Wageningen on October 21$^{th}$, 2008 and October 14$^{th}$, 2009, for their active participation and contribution to the presented assessment view design. We also thank the Dutch 'Space for Geo-Information' (RGI) innovation program for providing the necessary resources to conduct this research.

# Chapter 6

# General discussion

# 6 General Discussion

## 6.1 Introduction

The worldwide development of Spatial Data Infrastructures (SDIs) is growing and many are now widely used for finding, accessing and sharing spatial data. When developing SDIs it is increasingly important to justify the resources spent on those infrastructures. As a consequence, interest in SDI assessment research has grown in recent years. SDI assessment can be used to investigate whether the intended results of the SDIs are being delivered in an efficient way. It could also enrich our knowledge about SDI performance, which in turn can be used to improve the functioning of SDIs.

However, SDI assessment is problematic. One of the main obstacles is the complex nature of SDIs. Moreover, despite the fact that several SDI assessment approaches have already been developed, there is no assessment framework that can bring the existing approaches together to provide a more comprehensive SDI assessment. Such an assessment framework should also satisfy current user needs. The specific assessment requirements of SDI policy makers, coordinators and users can be met by offering them operational assessment tools for assessing the realization of SDI goals. The main objective of this thesis was to develop such a comprehensive SDI assessment framework. Four sub-objectives were set to structure the process of developing this framework:

1. to analyse SDI complexity;
2. to develop an SDI assessment framework;
3. to evaluate the developed SDI assessment framework;
4. to expand the developed SDI assessment framework by adding an assessment view for goal-oriented SDI assessment.

The research generated new results on SDI assessment and revealed certain limitations. This chapter contains a summary of the main findings for each sub-objective, a reflection on the thesis results and their implications for SDI assessment, a discussion of the limitations of SDI assessment encountered in the research process, and finally, suggestions for future research.

## 6.2 Main findings

*Sub-objective 1: to analyse SDI complexity*

SDIs are complex because of the large number and variety of stakeholders, their different needs and the complex relations between them. This complexity has led to some confusion within the SDI community about what exactly an SDI is, and no single definition has yet been agreed upon (Budhathoki & Nedovic-Budic, 2007; Chan, 2001; Craglia & Nowak, 2006; De Man, 2006a; Onsrud, 2007; Rajabifard, 2003). Also, little is known about how to deal with SDI complexity. For example, it has proved difficult to identify uniform criteria of merit against which SDIs can be assessed. Given this complexity, it was necessary to establish principles for effective SDI assessment.

This thesis reveals that SDIs can be viewed as Complex Adaptive Systems, which has implications for SDI assessment. It appears that the principles for assessing complex phenomena are also valid for SDI assessment. According to these principles, the dynamic nature of complex phenomena means that the assessment framework should be flexible and comprise multiple assessment strategies and methods. Moreover, any method for assessing complex phenomena should avoid oversimplifying them.

*Sub-objective 2: to develop an SDI assessment framework*

The principles of assessing Complex Adaptive Systems were used as a basis for developing an SDI assessment framework. Analysis of these principles and a review of the evaluation literature led to the conclusion that a flexible framework combining multiple assessment approaches and methods is the correct way to assess SDIs. The Multi-view SDI Assessment Framework developed in this thesis reflects that conclusion.

The strength of the Multi-view SDI Assessment Framework lies in the multiplicity of assessment views, methods and indicators used to assess specific SDIs. The flexibility of the framework permits the addition of new assessment views and the adjustment and removal of existing ones. Each view addresses a specific assessment purpose. Some assessment views can help in evaluating SDI performance, other views have the potential to deepen our knowledge about SDIs and may help to improve the quality of SDIs. This combination of different assessment views and purposes allows for a more comprehensive and less biased SDI assessment.

*Sub-objective 3: to evaluate the developed SDI assessment framework*

The evaluation literature advocates meta-evaluation (the evaluation of the assessment framework) as a crucial step in the process of developing an assessment framework (Scriven, 1969; 1991; Straw & Cook, 1990; Hanssen et al., 2008; Stufflebeam & Shinkfield, 2007). Meta-evaluation is important for checking the quality of evaluations and the conclusions drawn from them. Meta-evaluations are therefore important in ensuring the acceptance of and confidence in the developed assessment framework among its future users. Meta-evaluation is particularly important for ensuring the applicability and usability of the Multi-view SDI Assessment Framework because it comprises many assessment views, methods and indicators.

The pilot application of the framework demonstrated that it can be used to assess 21 national SDIs. The process of gathering the necessary data for assessing each national SDI took on average 51 days. It is common that for some assessment methods, the assessment data are missing. Therefore in the future applications of the framework and analysis of the assessment results, the methods of handling the missing values have to be consulted. Potential users judged the framework to be suitable for assessing SDIs. For example, the framework application helped the users to determine which aspects of their SDIs are relatively well developed and which still need improvement.

*Sub-objective 4: to expand the developed SDI assessment framework by adding an assessment view for goal-oriented SDI assessment*

The motives for building SDIs are often based on anticipated benefits for society, economy, environment, etc. Based on these widely articulated but rarely proven benefits, SDI coordinators in each country define more specific objectives for their SDIs. It is therefore imperative to assess how far the intended objectives have been realized. However, an operational assessment view for assessing the extent to which SDIs realize their specific goals does not exist. This thesis expands the developed Multi-view SDI Assessment Framework by adding an assessment view for assessing the realization of SDI goals. This assessment view was tested in the Dutch SDI context and evaluated by potential users.

The goal-oriented assessment view was developed in a stepwise manner using the Multi-view SDI Assessment Framework as the conceptual basis. The goal-oriented view can therefore be added to the existing array of assessment approaches that constitute the Multi-view SDI Assessment Framework. The pilot application of the goal-oriented SDI assessment view for the Dutch SDI provided sufficient grounds for assessing the extent to which the Dutch SDI goals have been realized. The potential users judged the developed goal-oriented view to be generic, objective, valid and cost-effective. However, due to the vaguely defined goals of the Dutch SDI, it was difficult to decide on the best indicators for measuring these goals.

## 6.3 Reflections

This section presents author's reflections on the main thesis results. These are grouped under four headings: 1) SDI complexity; 2) SDI assessment use; 3) evaluation discipline; and 4) future directions for SDI research and assessment.

*SDI complexity*

Author's analysis of SDI complexity draws on Complex Adaptive Systems (CAS) theory. CAS features and behaviours that are common for all complex adaptive systems were identified and described for three National SDIs. In addition, SDI experts were consulted about the use of CAS theory for analysing SDI complexity. The results show that the SDI concept can be viewed as a CAS irrespective of specific SDI instances, objectives or contexts. Further analysis of the principles of assessing CASs has contributed to the body of knowledge on SDI assessment by developing a framework built on these principles Furthermore, the proposed description of SDIs as CASs may help to explain the universal laws that govern SDI complexity and encourage SDI researchers to further investigate CAS features and behaviours. For example, the analysis of CAS features such as adaptability and self-organization in the SDI context may lead to a better understanding of the factors governing SDI sustainability or the ability of SDIs to meet changing user demands. Thorough analysis of CAS features and behaviours has also the potential to significantly improve the conceptualization of SDIs.

*The use of SDI assessment*

Crompvoets et al. (2008b) argue that the way in which an SDI should be assessed depends on the organizational level of the person carrying out the assessment. The Multi-view SDI Assessment Framework aims to address the different ways of assessing SDIs by offering assessment views suitable for three general assessment purposes: accountability, knowledge and development. It is anticipated that users at specific organizational levels will be linked to specific assessment purposes. For example, users at the strategic or management level will mainly be interested in accountability assessments. For instance, the goal-oriented SDI assessment view (see Chapter 5), designed for an accountability assessment, is used at the management level of the Dutch SDI to check how far the intended goals of the SDI are being realized and to inform the SDI stakeholder community about progress. In addition, the results are used in reporting to the strategic level of the Dutch SDI – the Ministry of VROM - to meet the requirement for periodic monitoring of the Dutch SDI (VROM, 2008). The INSPIRE State of Play, which can be classified as an assessment view for development and (partly) for accountability, was used from 2003 to 2007 by operational and management level EU policy makers to assist in the early stage of developing the concept of the European SDI (INSPIRE) (SADL, 2007). Although the assessment users at strategic, management and operational levels may have a preference for accountability, developmental and knowledge assessment views respectively, it must be stressed that this link between organizational levels and assessment purposes is only indicative in order to demonstrate the potential value of the Multi-view SDI Assessment Framework to users at all SDI organizational levels (see Figure 6.1).

The Multi-view SDI Assessment Framework is designed in such a way that users interested in assessing an SDI for one or more specific purposes and from specific views can potentially be served with a list of assessment approaches and indicators that best fit their assessment needs. Although such functionality has not been achieved in this thesis, it is recommended that future research on improving the functionality of the Multi-view SDI Assessment Framework considers this issue.

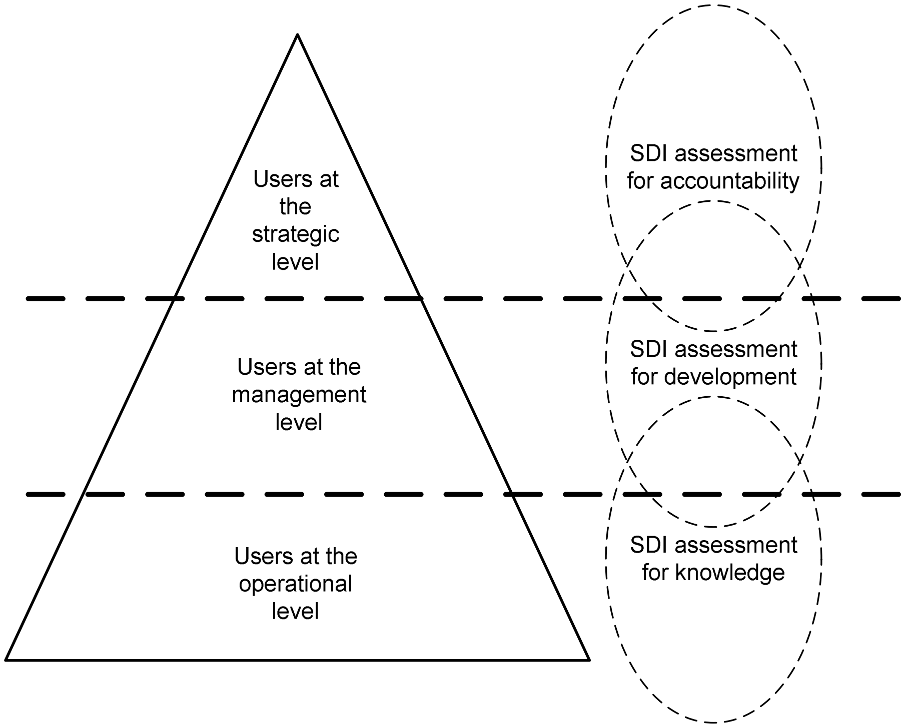


Figure 6.1. Relation between SDI assessment users at different organizational levels and their potential purposes of assessing SDIs

The Multi-view SDI Assessment Framework is conceptually based on the principles of assessing Complex Adaptive Systems, which state that the complex phenomena should not be oversimplified and that its components are interdependent and should not be analysed in isolation from each other. This implies that the maximum number of available assessment approaches should be used simultaneously to obtain the most accurate assessment of complex phenomena (see Chapter 2 section 2.7). However, this raises concerns about the usability of the framework. In practice, the simultaneous application of large number of diverse assessment approaches may well be unrealistic and so a limited selection of the assessment approaches will probably be used when applying the Multi-view SDI Assessment Framework. This means that a feasible SDI assessment will always be incomplete.

*Evaluation discipline*

In this thesis, the evaluation literature was extensively consulted to provide knowledge, tools and solutions for SDI assessment. For example, the scientists involved in the evaluation research field have already highlighted the concept of using multiple methods, dimensions and disciplines in evaluation practices

(Scriven, 1983; Denzin, 1990). However, the evaluation literature appears to lack operational concepts and practices specifically suited to evaluating complex systems. It seems that there is still a missing link between what the evaluation discipline offers and what complexity science requires for evaluating its systems. This thesis attempts to establish such a link. The fundamental principles for evaluating complex systems are explicitly articulated in this thesis. The Multi-view SDI Assessment Framework demonstrates how these principles are made operational. It is the author's hope that the experience of developing an assessment framework for SDI will also be used in the evaluation discipline to further analyse and propose solutions for assessing complex phenomena.

*Future directions for SDI research and assessment*

Current SDI research is considered to be too inward-looking, neglecting other disciplines, concepts and frameworks (Budhatoki and Nedovic-Budic, 2007). The future of SDI related research will require knowledge from other disciplines, such as economics, the social sciences, organizational studies, etc. (Masser, 2005b). Interdisciplinarity, if not transdisciplinarity, is considered the future direction for SDI related research (Bregt et al., 2009). In addition, it is anticipated that the community of SDI assessors will grow. This will result in increased interest in a wide range of disciplinary approaches to serve broad SDI assessment interests (Pollit, 2007; Crompvoets et. al., 2008b)

The Multi-view SDI Assessment Framework developed in this thesis attempts to address these future directions of SDI research and assessment by applying the CAS theory and consulting the evaluation community to provide the SDI community with new concepts and directions that can help them better understanding and improve SDIs. The developed framework recognizes the multidisciplinary views on SDI and supports a wide range of assessment purposes of a growing variety of users.

## 6.4 Limitations

During the research for this thesis some limitations of SDI assessment were encountered. Two of them are discussed here.

The relatively small number of operational SDI assessment views and their approaches limits the potential of the Multi-view SDI Assessment Framework for a comprehensive SDI assessment. For example, the pilot application of the framework (see Chapter 4) could only use four assessment approaches. This is not enough to address the various assessment needs of SDI assessors. In addition, the operational assessment approaches used are strongly based on the survey method for collecting assessment data. Therefore, the expected potential of the Multi-view SDI Assessment Framework for a realistic, less biased and more comprehensive SDI assessment (see Chapter 3) depends on the existence of a great variety of operational assessment approaches and methods of collecting assessment data (e.g. case studies, interviews, etc.).

When developing the SDI goal-oriented assessment view (see Chapter 5) it was impossible to use all the indicators proposed by SDI stakeholders as being most relevant. The reason was that some indicators could not be measured due to the limited availability of assessment methods and data, which in turn may be because SDI assessment is still in an early stage of development. Until recently, the focus of the SDI community was on developing, implementing and advocating the need for SDIs rather than on developing tools, methods and indicators to assess them. For example, when developing rules for monitoring the implementation and use of the INSPIRE directive, one of the most troublesome tasks was finding the proper indicator to measure the fundamental functionality of the European SDI, which is data sharing. This limited body of assessment knowledge, experience, tools and data is still a major obstacle to effective SDI assessment. However, these difficulties form an additional argument for using the developed Multi-view SDI Assessment Framework, with its multiplicity of indicators and assessment methods, instead of focusing on just one view with its specific indicators that might be relevant, but often not measurable.

## 6.5 Outlook

For the future research the following recommendations are given:

- Analyse the roles that CAS features and behaviours play in SDIs. In this thesis the author has identified the CAS features and behaviours in SDIs, but have not further analysed them. Further analysis of the nature of CAS features and behaviours in SDIs has the potential to deepen our knowledge about the reasons for SDI complexity and help with finding ways of dealing with this complexity.

- Focus on developing operational SDI assessment views suited to specific user needs. In this research the Multi-view SDI Assessment Framework could only be applied using four existing operational SDI assessment views. To provide the means for more comprehensive SDI assessment, more assessment views, approaches and methods (e.g. case studies, interviews) need to be developed.

- Identify the users of SDI assessment methods and their SDI assessment requirements. This would help with the design of more appropriate, more precise and more useful SDI assessments. The majority of existing SDI assessments were driven by curiosity and have been done for research purposes. The number of demand-driven SDI assessments, especially at the governmental level, is still limited (Lance et. al., 2006).

- Analyse the use of SDI assessment results (see Crompvoets et al., 2008b). For example, we still do not know what the consequences are of a positive or negative assessment result for the future development of an SDI. How can SDI coordinators or coordinating bodies use assessment results to improve their SDIs? How can assessments be used to generate a better understanding and explanation of the general concept of SDI? It is essential to address these questions so that the assessment results can ultimately be used to improve SDIs.

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# Appendices

## **Appendix 1**: Questionnaire results on Spatial Data Infrastructures as Complex Adaptive Systems.

| | | Responses | |
|---|---|---|---|
| | | % | Number |
| 1. SDI consists of recognizable components. (Components)* | | | |
| | Strongly agree | 7.4 | 2 |
| | Agree | 59.3 | 16 |
| | Neutral | 14.8 | 4 |
| | Disagree | 11.1 | 3 |
| | Strongly disagree | 7.4 | 2 |
| 2. SDI is isolated from its environment. (Openness)* | | | |
| | Strongly agree | 0.0 | 0 |
| | Agree | 0.0 | 0 |
| | Neutral | 3.8 | 1 |
| | Disagree | 42.3 | 11 |
| | Strongly disagree | 53.8 | 14 |
| 3. Decisions on SDI made in the past have an impact on its future development. (Sensitivity to initial conditions)* | | | |
| | Strongly agree | 25.9 | 7 |
| | Agree | 51.9 | 14 |
| | Neutral | 18.5 | 5 |
| | Disagree | 3.7 | 1 |
| | Strongly disagree | 0.0 | 0 |
| 4. New SDI functions can emerge in the future. (Unpredictability)* | | | |
| | Strongly agree | 37.0 | 10 |
| | Agree | 55.6 | 15 |
| | Neutral | 3.7 | 1 |
| | Disagree | 0.0 | 0 |
| | Strongly disagree | 3.7 | 1 |
| 5. The main SDI components are similar on different levels of SDI hierarchy, e.g. Local SDIs, National SDIs, etc. (Scale independence)* | | | |
| | Strongly agree | 7.4 | 2 |
| | Agree | 59.3 | 16 |
| | Neutral | 11.1 | 3 |
| | Disagree | 18.5 | 5 |
| | Strongly disagree | 3.7 | 1 |
| 6. SDI's future activities can be predicted with high certainty. (Unpredicability)* | | | |
| | Strongly agree | 0.0 | 0 |
| | Agree | 7.4 | 2 |
| | Neutral | 22.2 | 6 |
| | Disagree | 63.0 | 17 |
| | Strongly disagree | 7.4 | 2 |
| 7. SDI organizers may create their own organizational structure without necessarily being guided by an external, non-SDI body. (Self-organization)* | | | |
| | Strongly agree | 7.4 | 2 |
| | Agree | 48.1 | 13 |
| | Neutral | 22.2 | 6 |
| | Disagree | 18.5 | 5 |
| | Strongly disagree | 3.7 | 1 |
| 8. SDI behaviour may change in an unpredictable way due to | | | |

transformations in country's political strategies. (Non linearity)*

| | | |
|---|---|---|
| Strongly agree | 3.8 | 1 |
| Agree | 50.0 | 13 |
| Neutral | 23.1 | 6 |
| Disagree | 23.1 | 6 |
| Strongly disagree | 0.0 | 0 |

9. SDI is able to learn from its own experience and improve itself i.e. by changing its organizational structure to a more efficient one. (Feedback loop)*

| | | |
|---|---|---|
| Strongly agree | 7.4 | 2 |
| Agree | 63.0 | 17 |
| Neutral | 22.2 | 6 |
| Disagree | 7.4 | 2 |
| Strongly disagree | 0.0 | 0 |

10. It is difficult to identify SDI main building blocks. (Components)*

| | | |
|---|---|---|
| Strongly agree | 3.7 | 1 |
| Agree | 18.5 | 5 |
| Neutral | 14.8 | 4 |
| Disagree | 51.9 | 14 |
| Strongly disagree | 11.1 | 3 |

11. Complexity of SDI is a result of many actors constantly interacting with each other in a way which is hard to predict. (Complexity)*

| | | |
|---|---|---|
| Strongly agree | 19.2 | 5 |
| Agree | 50.0 | 13 |
| Neutral | 23.1 | 6 |
| Disagree | 3.8 | 1 |
| Strongly disagree | 3.8 | 1 |

12. Current SDI performance is independent of the decision made about it in the past. (Sensitivity to initial conditions)*

| | | |
|---|---|---|
| Strongly agree | 3.7 | 1 |
| Agree | 3.7 | 1 |
| Neutral | 3.7 | 1 |
| Disagree | 77.8 | 21 |
| Strongly disagree | 11.1 | 3 |

13. It is not easy to determine the boundaries of SDI. (Openness)*

| | | |
|---|---|---|
| Strongly agree | 22.2 | 6 |
| Agree | 55.6 | 15 |
| Neutral | 7.4 | 2 |
| Disagree | 14.8 | 4 |
| Strongly disagree | 0.0 | 0 |

14. SDI is able to change its own structure and strategies over time due to changing circumstances in its environment. (Adaptability)*

| | | |
|---|---|---|
| Strongly agree | 3.7 | 1 |
| Agree | 55.6 | 15 |
| Neutral | 33.3 | 9 |
| Disagree | 3.7 | 1 |
| Strongly disagree | 3.7 | 1 |

15. On different SDI's hierarchical levels the constituting components are similar. (Scale independence)*

| | | |
|---|---|---|
| Strongly agree | 0.0 | 0 |
| Agree | 59.3 | 16 |
| Neutral | 18.5 | 5 |
| Disagree | 18.5 | 5 |
| Strongly disagree | 3.7 | 1 |

16. SDI is able to adapt its functionality to the emerging advancements in other sectors. (Adaptability)*

| | | |
|---|---|---|
| Strongly agree | 3.7 | 1 |
| Agree | 48.1 | 13 |
| Neutral | 33.3 | 9 |
| Disagree | 11.1 | 3 |

| | | |
|---|---|---|
| Strongly disagree | 3.7 | 1 |

17. SDI development is linear i.e. given specifically defined system's setup it is possible to be sure about its behaviour. (Non linearity)*

| | | |
|---|---|---|
| Strongly agree | 0.0 | 0 |
| Agree | 3.8 | 1 |
| Neutral | 19.2 | 5 |
| Disagree | 42.3 | 11 |
| Strongly disagree | 34.6 | 9 |

18. Audits and evaluations (internal or/and external) help to improve SDI performance. (Feedback loop)*

| | | |
|---|---|---|
| Strongly agree | 22.2 | 6 |
| Agree | 51.9 | 14 |
| Neutral | 25.9 | 7 |
| Disagree | 0.0 | 0 |
| Strongly disagree | 0.0 | 0 |

19. SDI can be described as a set of components working together for a particular purpose. (System)*

| | | |
|---|---|---|
| Strongly agree | 11.5 | 3 |
| Agree | 42.3 | 11 |
| Neutral | 23.1 | 6 |
| Disagree | 19.2 | 5 |
| Strongly disagree | 3.8 | 1 |

20. SDI actors behave according to strictly defined rules and procedures. (Complexity)*

| | | |
|---|---|---|
| Strongly agree | 0.0 | 0 |
| Agree | 0.0 | 0 |
| Neutral | 40.7 | 11 |
| Disagree | 44.4 | 12 |
| Strongly disagree | 14.8 | 4 |

21. Bottom up processes play an essential role in shaping SDI. (Self-organization)*

| | | |
|---|---|---|
| Strongly agree | 25.9 | 7 |
| Agree | 63.0 | 17 |
| Neutral | 11.1 | 3 |
| Disagree | 0.0 | 0 |
| Strongly disagree | 0.0 | 0 |

* - the information in brackets was not included in the version of the questionnaire that was sent to the workshop participants.

## **Appendix 2**: Questionnaire to evaluate the relevance of assessing SDIs with the Multi-view SDI assessment framework.

Dear respondent,

The report that you received shows result of your NSDI assessment with 4 different assessment views (different approaches, indicators, measurement methods). To evaluate the relevance of assessing SDIs simultaneously with several assessment views we would like you to express your opinion about the following statements

**1. The assessment results are accurate and consistent.**

| Fully disagree | Disagree | Neutral | Agree | Fully agree |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

Your comments:

**2. The assessment results shown in the report allows for a more complete and realistic SDI assessment..**

| Fully disagree | Disagree | Neutral | Agree | Fully agree |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

Your comments:

**3. The conclusions from the assessment are objective.**

| Fully disagree | Disagree | Neutral | Agree | Fully agree |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

Your comments:

**4. The assessment results shown in the report help you decide which aspects of your SDI need enhancement.**

| Fully disagree | Disagree | Neutral | Agree | Fully agree |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

Your comments:

**5. The assessment can be seen as valid and unbiased.**

| Fully disagree | Disagree | Neutral | Agree | Fully agree |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

Your comments:

**6. The assessment is cost-effective in achieving the assessment results.**

| Fully disagree | Disagree | Neutral | Agree | Fully agree |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

Your comments:

**7. The Multi-view SDI assessment framework can be used to assess any SDIs.**

| Fully disagree | Disagree | Neutral | Agree | Fully agree |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

Your comments:

**8. The assessment results are verifiable.**

| Fully disagree | Disagree | Neutral | Agree | Fully agree |
| --- | --- | --- | --- | --- |
| ☐ | ☐ | ☐ | ☐ | ☐ |

Your comments:

**Appendix 3**: Multi-view SDI assessment report.

This report presents the results of the pilot application of the Multi-view SDI assessment framework (Grus et al., 2007). The Multi-view SDI assessment framework aims to assess one SDI from different perspectives (views). The results below should only be treated as an indication of the NSDI performance seen from 4 different perspectives. It is not an official NSDI performance report. We also know that this report have been done based on data from 2008 and since then the values of some indicators might have already changed.

<table>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2">Country name</td></tr>
<tr><td colspan="2">Assessment view 1<br>Data access facility assessment (Clearinghouse)<br>(based on Crompvoets et al., 2004)</td></tr>
<tr><td>Total score of assessment view 1</td><td>value in %</td></tr>
<tr><td colspan="2">Points of attention*:<br>-</td></tr>
<tr><td colspan="2">Assessment view 2<br>Assessment of organizational, legal, financial, metadata, data access and services and standards aspects<br>(based on INSPIRE State of Play approach (SADL, 2005))</td></tr>
<tr><td>Total score of assessment view 2</td><td>value in %</td></tr>
<tr><td colspan="2">Points of attention*:<br>-</td></tr>
<tr><td colspan="2">Assessment view 3<br>Organizational aspects based on Organizational approach<br>(based on Kok & van Loenen, 2005)</td></tr>
<tr><td>Total score of assessment view 3:<br>(4 possible stages of SDI development from the least to the most mature [left to right]: Stand-alone; Exchange; Intermediary and Network)</td><td>stage name</td></tr>
<tr><td colspan="2">Points of attention*:<br>-</td></tr>
<tr><td colspan="2">Assessment view 4<br>Assessment of your country’s preparedness to embrace SDI<br>(based on Delgado Fernández et al., 2005)</td></tr>
<tr><td>Total score of assessment view 4</td><td>value in %</td></tr>
<tr><td colspan="2">Points of attention*:<br>- Low level funding by means of the application of policies regarding cost recovery</td></tr>
<tr><td>Short summary</td><td>In our ranking of 21 NSDIs assessed with 4 different perspectives and methods of the Multi-view SDI assessment framework the (country) NSDI has ranked the 1st place. In order to improve, please look at the points of attention. If you are interested in detailed data, indicators values concerning this report and ranking of the assessed NSDIs please contact lucas.grus@wur.nl.</td></tr>
</table>

*Questions that have not been answered or marked as ‘Not sufficient information for assessment’ has been treated as 0 points.

**Appendix 4** Criteria for conducting meta-evaluation

**Stufflebeam's Meta-Evaluation Criteria**

| | |
|---|---|
| I. Technical Adequacy Criteria | A. Internal Validity: Does the assessment design unequivocally answer the question it was intended to answer?<br>B. External Validity: Do the assessment results have the desired generalizability? Can the necessary extrapolations to other populations, other program conditions, and other times be safely made?<br>C. Reliability: Are the assessment data accurate and consistent?<br>D. Objectivity: Would other competent assessors agree on the conclusion of the assessment? |
| II. Utility Criteria | A. Relevance: Are the findings relevant to the audiences of the assessment?<br>B. Importance: Have the most important and significant of the potentially relevant data been included in the assessment?<br>C. Scope: Does the assessment information have adequate scope?<br>D. Credibility: Do the audiences view the assessment as valid and unbiased?<br>E. Timeliness: Are the results provided to the audiences when they are needed?<br>F. Pervasiveness: Are the results disseminated to all of the intended audiences? |
| II. Efficiency Criterion | A. Is the assessment cost-effective in achieving the assessment results? |
| Note: criteria derived from Stufflebeam, 1974 (a) | |

**Appendix 5:** List of potential indicators for assessing SDIs.

- ☐ 1. There are one or more on-line services to download core spatial datasets that contribute the national SDI-initiative.
- ☐ 2. An organization of the type 'National GI-association is involved in the coordination of the national SDI
- ☐ 3. Existence of individual leadership (champion)
- ☐ 4. The national SDI-initiative is supported by someone with strong leadership
- ☐ 5. Use of maps for searching in the national SDI geoportal
- ☐ 6. There is a pricing framework for trading, using and/or commercializing geo-information
- ☐ 7. Last national SDI geoportal web address change.
- ☐ 8. There are one or more web mapping service available for core spatial data
- ☐ 9. The initiative and territorial coverage is truly national
- ☐ 10. Nature of participants' involvement in building NSDI
- ☐ 11. There is an independent thematic environmental SDI.
- ☐ 12. The long-term financial security of the national SDI-initiative is secured
- ☐ 13. Level of SDI funding from the government
- ☐ 14. There is a policy focusing on the access of thematic environmental data
- ☐ 15. Monthly number of visitors of the national SDI geoportal
- ☐ 16. Organizations which have agreed to the long term NSDI vision or strategic plan
- ☐ 17. There is a coordinating authority for metadata implementation at the level of the SDI
- ☐ 18. The SDI-initiative can be implemented by enough qualified staff capable to lead and work in national SDI-initiatives.
- ☐ 19. Existence of commitment building fora or platforms for NSDI
- ☐ 20. There have been taken initiatives in your country to launch the development of a National Spatial Data Infrastructure (SDI).
- ☐ 21. Network architecture of the national SDI geoportal
- ☐ 22. The national SDI-initiative takes into consideration capacity building issues in order to perform appropriate tasks within the broad set of principles relating your SDI-initiatives
- ☐ 23. Existence of long-term vision statement or strategic plan for your NSDI
- ☐ 24. There are true Public-Private Partnerships or other co-financing mechanisms between public and private sector bodies with respect to the development and operation of the national SDI-related projects.
- ☐ 25. Frequency of the national SDI geoportal website updates
- ☐ 26. Geo-Information can specifically be protected by copyright
- ☐ 27. Availability of view (web mapping) services in the national SDI geoportal

☐ 28. The geodetic reference system and projection systems are standardized, documented and interconvertable

☐ 29. The national language is the operational language of the national SDI

☐ 30. Availability in digital format of core spatial datasets crucial for the national SDI

☐ 31. English is used as secondary language.

☐ 32. Metadata-standard applied in the national SDI geoportal

☐ 33. The officially recognized or de facto coordinating body of the national SDI is a national organization

☐ 34. One national on-line access service for metadata (clearinghouse) is available providing metadata of more than one data producing agency

☐ 35. There is documented data quality control procedures applied at the level of the national SDI

☐ 36. Types and extent of participants involved in building the NSDI and their roles

☐ 37. Number of data suppliers in the national SDI geoportal

☐ 38. One or more standardized metadata catalogues are available covering more than one data producing agency

☐ 39. There is an institutional framework or policy for sharing geo-information between public institutions

☐ 40. Kind of NSDI leadership

☐ 41. Availability of commercial or in-house spatially- related software

☐ 42. Number of thematic environmental datasets available in the national SDI geoportal

☐ 43. Metadata are produced for a significant fraction of spatial datasets

☐ 44. Only public sector actors are participating in the national SDI

☐ 45. Nature of the institution(s) with a role of SDI leader

☐ 46. The officially recognized or de facto coordinating body for the national SDI is an organization controlled by data users

☐ 47. Thematic environmental data are covered by the described SDI-initiative

☐ 48. Metadata Availability

☐ 49. Recognition (for example, in Governmental laws or formal orders) of the need to establish or further develop NSDI

☐ 50. Most spatial datasets are available in digital format that provide a basis for contributing the national SDI-initiative

☐ 51. Availability of data download services in the national SDI geoportal

☐ 52. The national SDI-initiative is devoting significant attention to standardization issues

☐ 53. The level of legal support for SDI framework (existence of legal instruments such as laws, policies, directives and commitments

☐ 54. There are simplified and standardized licenses for personal use

☐ 55. Use of Open source services

☐ 56. Privacy laws are actively being taken into account by the holders of geo-information

☐ 57. There is a legal instrument or framework determining the SDI-strategy or development

☐ 58. Languages used in the national SDI geoportal

☐ 59. Concern for interoperability goes beyond conversion between data formats

☐ 60. Nature of a vision and strategies to accomplish SDI

☐ 61. SDI community addresses issues arising from society to which geographic information may contribute

☐ 62. Number of datasets available in the national SDI geoportal

☐ 63. Metadata records of thematic environmental datasets in the national SDI geoportal

☐ 64. Level of capacity building and awareness of the SDI impact on well functioning of society including business, public, and academia

☐ 65. Level of funding by means of cost recovery

☐ 66. Spatial data producers as well as end users are participating in the national SDI

☐ 67. Funding continuity of the national SDI geoportal

☐ 68. Level of private and enterprise sector funding

☐ 69. There is a freedom of information (FOI) act which contains specific FOI legislation for the GI-sector.

☐ 70. Involvement of private parties in developing the long term vision or strategic plan of NSDI

☐ 71. Mechanisms for searching available in the national SDI geoportal

☐ 72. Most recently produced dataset available in the national SDI geoportal

## **Appendix 6**: Questionnaire to conduct a meta-evaluation of the Multi-view SDI assessment framework application results.

**Meta-evaluation.**

Dear participant,

In order to evaluate the goal oriented SDI assessment approach we would like you to answer the following questions:

**1. The assessment approach design clearly answers the question it was intended to answer.**

Fully disagree 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ Fully agree

Your comments:

**2. The assessment approach can also be used to assess other SDIs than the Dutch one.**

Fully disagree 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ Fully agree

Your comments:

**3. The assessment results are accurate and consistent.**

Fully disagree 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ Fully agree

Your comments:

**4. The conclusions from the assessment are objective.**

Fully disagree 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ Fully agree

Your comments:

**5. The findings of the assessment are relevant to those interested in GIDEON goals monitoring.**

Fully disagree 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ Fully agree

Your comments:

**6. All important and relevant indicators have been included in the assessment.**

Fully disagree 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ Fully agree

Your comments:

**7. The assessment has an adequate scope.**

Fully disagree 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ Fully agree

Your comments:

**8. The assessment can be seen as valid and unbiased.**

Fully disagree 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ Fully agree

Your comments:

**9. The approach can always be used whenever it is needed to measure the extend to which SDI goals are met.**

Fully disagree 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ Fully agree

Your comments:

**10. The assessment is cost-effective in achieving the assessment results.**

Fully disagree 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ Fully agree

Your comments:

Thank you for your contribution.

# Summary

Over the last two decades many countries throughout the world have taken steps to establish national Spatial Data Infrastructures (SDIs). These actions have sought to provide an infrastructure for accessing and sharing spatial data to reduce the duplication of spatial data collection by both users and producers, and enable better utilization of spatial data and associated services. When developing SDI initiatives it is increasingly important to assess their outcomes in order to justify the resources spent on those infrastructures. Many researchers throughout the world have been struggling with the issue of assessing SDIs. The task is difficult due to complex, dynamic and constantly evolving nature of SDI.

The main objective of this thesis is to develop a framework for assessing Spatial Data Infrastructures. This main objective is divided into four sub-objectives:

1. to analyse SDI complexity;
2. to develop a SDI assessment framework;
3. to evaluate the developed SDI assessment framework;
4. to expand the developed SDI Assessment Framework by adding an assessment view for a goal-oriented SDI assessment.

Each of these four sub-objectives are analysed in chapters 2-5.

Chapter 2 analyses SDI complexity by determining whether SDIs can be viewed as Complex Adaptive Systems (CAS). This was done by analyzing three NSDI case studies and conducting a survey among SDI experts. First, it was determined if CAS features and behaviours could be found in the three analyzed NSDIs. The author searched for the following CAS features and behaviours: 1) features: components, complexity, sensitivity to initial conditions, openness, unpredictability and scale independence; 2) behaviours: adaptability, self-organization, non-linear behaviour, feedback loop mechanism. Second, a survey among SDI experts was conducted by asking them to express their strength of support regarding the presence of CAS features and behaviours in general SDI concept. The results reveal that SDIs can be viewed as CAS.

Chapter 3 develops a SDI assessment framework. First, the key SDI characteristics that underlie the problems affecting SDI assessment were

identified and analyzed. In order to deal with these problems the principles of assessing Complex Adaptive Systems were identified and discussed. The principles of evaluating Complex Adaptive Systems and norms of general evaluation theory were the basis for developing an assessment framework. The principles of assessing CAS, among others, require that the assessment framework is flexible, contains multiple assessment approaches and uses various methods to determine the indicators' values. The result is the Multi-view SDI assessment framework.

Chapter 4 evaluates the Multi-view SDI assessment framework. The evaluation was based on the pilot application of the framework in 21 National SDIs. The evaluation focused on the process of framework application and framework's applicability to assess SDIs. The process of framework application was evaluated against two criteria: 1) NSDI coordinator response time; 2) Completeness of data. The applicability of the framework to assess SDIs was evaluated by sending a questionnaire to 21 NSDI coordinators. The coordinators were asked for the opinion about the applicability of Multi-view SDI assessment framework application results to assess SDIs. The questionnaire was based on meta-evaluation standard criteria for conducting evaluations (Stufflebeam, 1974; The Joint Committee, 1994). The results showed that the framework could be applied to assess 21 NSDIs. The evaluation of the application process revealed that the completeness of assessment data and time needed to measure indicators depends strongly on the assessment methods used. In addition, the results showed that significant part of the measurements contained missing values. Finally it was demonstrated that the users tend to agree with the general applicability of the Multi-view SDI assessment framework to assess SDIs.

Chapter 5 expands the developed SDI Assessment Framework by adding an assessment view for a goal-oriented SDI assessment. The conceptual foundation of the developed assessment view was a goal-attainment assessment model presented by Hansen (2005). The model seeks to answer the question: to what degree has the goals been realized? The model derives the assessment criteria from goals. To develop a goal-oriented assessment view the author used the Multi-view SDI assessment framework. The developed assessment view was tested by applying it to measure the goals' realization of the Dutch SDI. In addition, the potential users of the goal-oriented assessment view evaluated it. The main result of this chapter is the view for assessing the extent to which SDIs realize their goals. The implementation of the proposed view in the Dutch SDI case demonstrates its potential application. In addition, the evaluation of the proposed view conducted among the potential users confirms its usability and generic character. It is also argued that the precision of definition of SDI goals determines how easy the correct assessment indicators can be found.

Chapter 6 discusses the results of the thesis, presents author's reflections on the main results, and suggests recommendations for the future research. In order to better assess SDIs researchers should look for theories, which could explain and help to understand SDI mechanisms and laws. The results show that viewing SDI as CAS is beneficial for better understanding of SDI assessment principles. As a result, the Multi-view SDI assessment framework is proposed. However, due to the practical reasons it is hypothesized that a fully comprehensive SDI assessment might never be achieved. The reflections on the thesis results lead to several conclusions. Firstly, viewing SDI as CAS, apart from helping to assess SDIs, has also a potential to significantly improve the conceptualization of SDI. Secondly, the proposed Multi-view SDI assessment framework demonstrates the potential value for SDI assessment users acting on all SDI organizational levels. Thirdly, the experience of developing an assessment framework for SDI may also be used in evaluation discipline to further analyze and propose solutions for assessing complex phenomena. Fourthly, the proposed framework has also potential to contribute to an emerging trend of the inter- and transdisciplinary approaches to researching and assessing SDIs. The following recommendations for the future research are made: 1) Analyze the roles that CAS features and behaviours play in SDIs; 2) Focus on developing operational SDI assessment approaches suited to specific user's needs; 3) Analyze the users and their requirements of SDI assessment; 4) Analyze the use of SDI assessment results.

# Samenvatting

In de afgelopen twee decennia hebben landen over de gehele wereld stappen ondernomen om een nationale Geo-informatie infrastructuur (SDI) te ontwikkelen. Het doel hiervan is om ruimtelijke gegevens toegankelijk en uitwisselbaar te maken, duplicatie van ruimtelijke gegevens door gebruikers en producenten te verminderen en de ruimtelijke gegevensverzamelingen en bijbehorende diensten beter bruikbaar te maken. Bij het ontwikkelen van SDI initiatieven wordt het steeds belangrijker hun prestaties en resultaten te beoordelen om de investeringen in deze infrastructuren te rechtvaardigen. De afgelopen jaren hebben diverse onderzoekers zich gebogen over de vraag: op welke wijze kunnen we SDI's evalueren? Het blijkt dat deze vraag lastig eenduidig te beantwoorden is als gevolg van complexe, dynamische en constant veranderende karakter van SDI.

De hoofddoelstelling van dit onderzoek is de ontwikkeling van raamwerk ter beoordeling van Geo-Informatie Infrastructuren. Om dit hoofddoelstelling te bereiken zijn de vier deeldoelstellingen geformuleerd:

1. Het analyseren van SDI complexiteit;
2. Het ontwikkelen van een SDI beoordelingsraamwerk;
3. Het evalueren van de ontwikkelde SDI beoordelingsraamwerk;
4. Het uitbreiden van de ontwikkelde SDI beoordelingsraamwerk door toevoeging van een doelgerichte SDI beoordeling methodiek.

Deze vier deeldoelstellingen worden in de hoofdstukken 2-5 verder uitgewerkt.

Hoofdstuk 2 analyseert SDI complexiteit door te onderzoeken of SDI gezien kan worden als een complex adaptief systeem (CAS).Het onderzoek werd uitgevoerd door het analyseren van drie Nationale SDI (NSDI) en het uitvoeren van een enquête onder SDI deskundigen. Eerst werd vastgesteld of CAS kenmerken en gedragingen kunnen worden gevonden in de drie geanalyseerd NSDIs. De auteur zocht naar de volgende CAS kenmerken en gedragingen: 1) kenmerken: componenten, complexiteit, gevoeligheid voor beginvoorwaarden, openheid, onvoorspelbaarheid, en schaal onafhankelijkheid; 2) gedragingen: aanpassingsvermogen, zelforganisatie, niet-lineaire gedrag, feedback loop mechanisme. Ten tweede werd een enquête onder SDI deskundigen uitgevoerd. Zij werden gevraagd naar mening over de aan- en afwezigheid van CAS

kenmerken en gedragingen in het algemeen SDI-concept. De resultaten tonen aan dat SDI kan worden gezien als CAS.

In hoofdstuk 3 wordt de ontwikkeling van een SDI beoordelingraamwerk beschreven. Allereerst worden de huidige problemen met SDI beoordelingen geïdentificeerd en geanalyseerd. Voor de oplossing voor de geconstateerde problemen is gebruik gemaakt van de algemene principes voor het evalueren van complex adaptieve systemen. Deze CAS evaluatie principes gecombineerd met algemene evaluatie theorie vormden de basis voor de ontwikkelen van een SDI beoordelingsraamwerk. De CAS evaluatie principes houden in dat het beoordelingsraamwerk flexibel dient te zijn en uit meerdere beoordelingsbenaderingen dient te bestaan. Op basis van deze principes is het Multi-view beoordelingsraamwerk voor SDI’s ontwikkeld.

In hoofdstuk 4 wordt het ontwikkelde Multi-view SDI beoordelingsraamwerk geëvalueerd. De evaluatie is gebaseerd op de toepassing van het raamwerk in 21 Nationale SDI's. De evaluatie richt zich op het proces van toepassing en de algemeen toepasbaarheid van het raamwerk om SDI's te beoordelen. Het toepassingsproces is geëvalueerd op basis van twee criteria: 1) NSDI coördinator reactie tijd en 2) volledigheid van de beoordelingsgegevens. De toepasbaarheid van het raamwerk is geëvalueerd door het sturen van een vragenlijst naar 21 NSDI coördinatoren. De vragenlijst is gebaseerd op meta-evaluatie standaard criteria voor het uitvoeren van evaluaties (Stufflebeam, 1974; The Joint Committee, 1994). De resultaten tonen aan dat het raamwerk toegepast kan worden in 21 NSDIs. Uit de beoordeling is gebleken dat de volledigheid van de beoordelingsgegevens en de tijd die nodig is om de indicatoren te meten sterk afhankelijk is van de gebruikte evaluatiemethoden. Tenslotte bleek dat de geënquêteerde NSDI coördinatoren het Multi-view SDI beoordelingsraamwerk toepasbaar achten.

Hoofdstuk 5 beschrijft de uitbreiding van het ontwikkelde Multi-view SDI beoordelingsraamwerk door toevoeging van een doelgerichte SDI beoordelingsmethode. De conceptuele basis voor deze nieuwe methode is het “goal-attaintment model” ontwikkeld door Hansen (2005). De ontwikkelde beoordelingsmethode is bedoeld om de vraag: “in welke mate zijn de doelstellingen gerealiseerd?” te antwoorden. De beoordelingscriteria van de methode zijn afgeleid van de doelen. Voor het ontwikkelen van de doelgerichte beoordelingsmethode heeft de auteur gebruik gemaakt van onderdelen van het Multi-view SDI beoordelingsraamwerk. De ontwikkelde methode is getest door meting van de mate van doelrealisatie van de Nederlandse Geo-informatie infrastructuur (GIDEON). Bovendien hebben de potentiële gebruikers de ontwikkelde methode beoordeeld. Uit de toepassing van de ontwikkelde methode bleek dat het mogelijk is om de mate van doelrealisatie van SDI's te meten. De bruikbaarheid en het generieke karakter van de methode is ook bevestigd door de potentiële gebruikers. Uit de toepassing bleek tevens dat de mate van concreetheid van de SDI doelen sterk bepaald is voor het formuleren van de beoordelingsindicatoren.

In hoofdstuk 6 wordt gereflecteerd op de resultaten van het onderzoek en worden aanbevelingen geformuleerd voor vervolgonderzoek. De resultaten laten zien dat belangrijk is om naar een onderliggende theorie of theorieën voor SDI te streven. In dit proefschrift is bijvoorbeeld de analogie tussen SDI en CAS gebruikt om de evaluatie van SDI's beter te begrijpen. Op basis van deze analogie is het Multi-view SDI beoordelingsraamwerk ontwikkeld.

Op basis van het uitgevoerde onderzoek zijn de volgende algemene conclusies te trekken. Ten eerste, is het een verrijking om SDI als een Complex Adaptief Systeem (CAS) te beschouwen. Dit leidt tot een beter begrip van het SDI fenomeen. Ten tweede, is het voorgestelde Multi-view SDI beoordelingsraamwerk generiek van aard en kan het worden toegepast bij het evalueren van uiteenlopende SDI's. Ten derde, blijkt het beoordelingsraamwerk flexibel en kan het worden uitgebreid met nieuwe beoordelingsmethoden.

Het onderzoek naar de evaluatie van SDI's is met dit proefschrift zeker niet af. Als mogelijke lijnen voor vervolgonderzoek wordt voorgesteld om: 1) de CAS aspecten binnen SDI nader te bestuderen; 2) specifieke gebruikersbehoeften voor SDI evaluatie nader te analyseren en 3) het gebruik van uitgevoerde SDI evaluaties te onderzoeken.

# Streszczenie

W ostatnich dwóch dekadach wiele krajów podjęło działania mające na celu utworzenie krajowych Infrastruktur Danych Przestrzennych (ang. Spatial Data Infrastructures [SDI]). Infrastruktury Danych Przestrzennych mają ułatwić dostęp i korzystanie z zasobów danych przestrzennych przez wielu różnorodnych użytkowników. Koncepcja takiej infrastruktury oparta jest na ujednolicaniu technologii, przepisów i standardów związanych z korzystaniem z danych przestrzennych oraz usług z nimi związanych. W ramach regionalnych, krajowych bądź lokalnych inicjatyw SDI, na znaczeniu zyskuje problematyka metod oceny tych infrastruktur. Funkcjonalne metody ocen SDI pozwoliłyby usprawniać procesy wdrażania i funkcjonowania SDI oraz pomogłyby lepiej kontrolować i uzasadniać wydatkowane na nie środki finansowe. Doświadczenie pokazuje jednak, że całościowa ocena funkcjonowania SDI nadal sprawia wiele trudności. Spowodowane jest to głównie kompleksowością, dynamiką a także ich ciągłą ewolucją tych infrastruktur.

Celem niniejszej pracy jest opracowanie metodyki ocen Infrastruktur Danych Przestrzennych. Cel ten realizowany jest w czterech etapach.

1. Analiza kompleksowości SDI;
2. Opracowanie metodyki ocen SDI;
3. Ocena opracowanej metodyki ocen SDI;
4. Rozszerzenie opracowanej metodyki o podejście oceniające stopień realizacji założonych celów SDI.

Każdy z wyżej wymienionych etapów omówiony został w rozdziałach od 2 do 5.

Rozdział drugi skupia się na analizie kompleksowości SDI poprzez porównanie ich do Kompleksowych Systemów Adaptacyjnych (ang. Complex Adaptive Systems [CAS]). Do analizy porównawczej posłużyły trzy studia przypadków Krajowych SDI oraz wyniki konsultacji ze specjalistami z zakresu SDI. Analiza trzech studiów przypadków polegała na próbie zidentyfikowania typowych cech i zachowań Kompleksowych Systemów Adaptacyjnych w każdym z analizowanych SDI. Analizie poddane zostały następujące cechy i zachowania systemów CAS: 1) cechy: komponenty (ang. components), kompleksowość (ang. complexity), wrażliwość systemu na warunki początkowe (ang. sensitivity to initial conditions), otwartość (ang. openness), nieprzewidywalność (ang. unpredictibility), niezależność struktury systemu od przyjętej skali analizy (ang.

scale independence); 2) zachowania: zdolność do adaptacji (ang. adaptability), samoorganizacja systemu (ang. self-organization), nieliniowość (ang. non-linearity), sprzężenia zwrotne (ang. feedback Loos). Poza analizą studiów przypadków, specjaliści z zakresu SDI zostali poproszeni o wyrażenie opinii co do podobieństwa SDI i CAS. Wyniki analizy studiów przypadków oraz opinie specjalistów wskazują, że Infrastruktury Danych Przestrzennych (SDI) mogą być widziane jako Kompleksowe Systemy Adaptacyjne (CAS).

Rozdział trzeci skupia się na opracowaniu metodyki oceny SDI. Bazą koncepcyjną metodyki była analiza zasad ocen CAS i zaadaptowanie ich do metodyki oceny SDI. Zasady ocen CAS zakładają między innymi stosowanie wielu różnych podejść i metod oceny komponentów systemu oraz elastyczność samej metodyki. Wynikiem tej części pracy jest tzw. „Wielopodejściowa metodyka oceny SDI".

Rozdział czwarty skupia się na ocenie procesu wdrażania i użyteczności proponowanej metodyki ocen SDI. Proces wdrażania metodyki oceniony został pod względem dwóch kryteriów: 1) czasu gromadzenia danych dla potrzeb oceny konkretnych krajowych SDI; 2) kompletności danych dla poszczególnych podejść opracowanej metodyki. Ocena procesu wdrażania została przeprowadzona na bazie danych uzyskanych z pilotażowego wdrożenia opracowanej metodyki. Pilotażowe wdrożenie opracowanej metodyki opierało się na danych uzyskanych od koordynatorów Krajowych Infrastruktur Danych Przestrzennych w 21 krajach. Po wdrożeniu opracowanej metodyki koordynatorzy zostali poproszeni o wyrażenie opinii na temat użyteczności metodyki do ocen Infrastruktur Danych Przestrzennych poprzez wypełnienie specjalnie przygotowanego kwestionariusza. Pytania z kwestionariusza oparte były na kryteriach używanych do oceniania przydatności metodyk ocen (tzw. Meta-oceny) (Stufflebeam, 1974; The Joint Committee, 1994). Wyniki tej części pracy wskazują, że metodyka z powodzeniem mogła być wdrożona do oceny 21 Krajowych Infrastruktur Danych Przestrzennych. Analiza procesu wdrażania metodyki wskazuje, że czas gromadzenia danych potrzebnych do oceny SDI oraz kompletność tych danych znacznie różni się pomiędzy poszczególnymi podejściami. Znaczna część danych potrzebnych do oceny SDI nie mogła być zgromadzona z uwagi na brak źródeł danych. Niemniej jednak wyniki kwestionariusza wysłanego do 21 koordynatorów Krajowych Infrastruktur Danych Przestrzennych wskazują, że większość z nich potwierdza użyteczność opracowanej metodyki do oceny Infrastruktur Danych Przestrzennych.

Rozdział piąty rozszerza opracowaną metodykę oceny SDI o podejście skupiające się na ocenie stopnia realizacji celów SDI. Opracowane podejście bazuje na ogólnej koncepcji oceny realizacji celów przedsięwzięć opracowanej przez Hansena (2005). Celem opracowanego podejścia jest znalezienie odpowiedzi na pytanie: w jakim stopniu założone cele przedsięwzięcia zostały osiągnięte? Kryteria oceny dla omawianego podejścia wyodrębniane są poprzez dokładną analizę znaczeniową założonych celów. Opracowane podejście zostało przetestowane poprzez wdrożenie go do oceny stopnia realizacji celów Holenderskiego SDI. Ponadto, potencjalni użytkownicy opracowanego podejścia zostali poproszeni o wyrażenie opinii na temat jego użyteczności. Wyniki wdrożenia omawianej metodyki w Holenderskim SDI oraz jej ocena poprzez potencjalnych użytkowników wskazują na jej użyteczność do oceny stopnia realizacji celów założonych przez SDI. Istotnym wnioskiem płynącym z wdrożenia opracowanej metodyki jest to, że precyzja zdefiniowania celów SDI ma fundamentalne znaczenie dla dokładności późniejszych ocen stopnia realizacji celów konkretnego SDI.

Rozdział szósty omawia kluczowe wyniki pracy, prezentuje refleksje autora oraz sugeruje kierunki dalszych prac badawczych w zakresie ocen Infrastruktur Danych Przestrzennych. Kluczowe wyniki tej pracy podkreślają konieczność ciągłego poszukiwania teorii, które pomogłyby lepiej zrozumieć koncepcje i mechanizmy rządzące SDI oraz pomogłyby oceniać ich funkcjonowanie w sposób całościowy. Przykładem jest teoria opisująca Kompleksowe Systemy Adaptacyjne, która zastosowana do analizy Infrastruktur Danych Przestrzennych pomogła lepiej zrozumieć zasady przeprowadzania ich ocen. Na podstawie tych zasad zaproponowana została tzw. „Wielopodejściowa metodyka oceny SDI”. Jednakże, z powodu wciąż znikomej ilości podejść do oceny SDI, całościowa ocena SDI może być niezwykle trudna do zrealizowana. Refleksje autora na wyniki pracy prowadzą do następujących wniosków. Po pierwsze, widzenie Infrastruktur Danych Przestrzennych jako Kompleksowych Systemów Adaptacyjnych, oprócz lepszego zrozumienia zasad oceny tych infrastruktur, pozwala na lepsze zrozumienie samej koncepcji SDI. Po drugie, zaproponowana „Wielopodejściowa metodyka oceny SDI” ma zastosowanie dla użytkowników wszystkich szczebli organizacyjnych SDI. Po trzecie, wyniki pracy związane z opracowywaniem metodyki ocen SDI, mogą mieć również zastosowanie w innych dyscyplinach stykających się z problematyką ocen systemów kompleksowych. Po czwarte, ze względu na szeroki wachlarz metod ocen pochodzących z różnych dziedzin, wielopodejściowa metodyka oceny SDI jest zgodna z obecnie zyskującym na znaczeniu nurcie wielodyscyplinarnego podejścia do badań nad SDI. Jako kontynuację niniejszej pracy sugerowane są następujące kierunki prac badawczych: 1) Analiza ról jakie odgrywają cechy i zachowania Kompleksowych Systemów Adaptacyjnych w Infrastrukturach Danych Przestrzennych; 2) Opracowywanie funkcjonalnych podejść do oceny SDI, nastawionych w szczególności na realizację bieżących potrzeb użytkowników zajmujących się ocenianiem SDI; 3) Analiza charakterystyki użytkowników i ich wymagań w zakresie oceny SDI; 4) Analiza rzeczywistego wykorzystywania wyników oceny SDI.

# Curriculum Vitae

Łukasz Grus was born in Warsaw, Poland, on 18th May 1980. From 1999 to 2004 he studied Spatial Economics at the Warsaw University of Live Sciences. From September 2003 until February 2004, he was a student of the Socrates Erasmus Exchange Program at the Wageningen University, The Netherlands. After obtaining his first MSc. degree in Spatial Economics in Poland, he started his second MSc. in Geo-information Sciences at Wageningen University, which he finished in 2006. At the end of 2005, he started already with his PhD research at the Laboratory of Geo-information Science and Remote Sensing of Wageningen University. His research addressed the assessment of the Spatial Data Infrastructures. The research was funded by the Dutch innovation program Space for Geo-information. During his research, he had also an opportunity to contribute to the development of a method for assessing the Dutch Spatial Data Infrastructure required by the Ministry of Housing, Spatial Planning and Environment and developed by Geonovum. The results of his research have been published in scientific journals and at international conferences. In 2007, he spent 3 months at the Centre for Spatial Data Infrastructures and Land Administration at The University of Melbourne in Australia exploring the fundamental concepts of SDI. In May/June 2008, he had also an opportunity to visit the Geoconnections SDI program in Ottawa, Canada to analyse the practical implementation of SDIs and challenges of its assessment. Since the beginning of 2009, he has been sharing his time between finishing PhD thesis and lecturing in the MSC. course ‘Spatial Data Infrastructure’ of Wageningen University and the module ‘Management of GI-organizations’ of the joint MSc. course Geographical Information Management and Applications (GIMA) of Delft University of technology, Utrecht University, International Institute for Geo-Information Science and Earth Observation, and Wageningen University. He is also a happy husband of Magdalena and a proud father of Antoni and Jan.

# Publications list

### Peer reviewed publications

Grus, L., Crompvoets, J. & Bregt, A.K., 2010. Spatial Data Infrastructures as Complex Adaptive Systems. *International Journal of Geographical Information Science,* 24(3), pp.439-463.

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Grus, L., Bregt, A.K., Crompvoets, J., Castelein, W. & Rajabifard, A., 2009. Developing a goal-oriented SDI assessment approach using GIDEON – the Dutch SDI implementation strategy – as a case study. In: *11th International*

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**Other publications**

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Available online at:http://www.grs.wur.nl/UK/Workshops/Exploring+Spatial+Data+Infrastructures/Program/ [accessed 18 May 2008].

# PE&RC PhD Education Certificate

With the educational activities listed below the PhD candidate has complied with the educational requirements set by the C.T. de Wit Graduate School for Production Ecology and Resource Conservation (PE&RC) which comprises of a minimum total of 32 ECTS (= 22 weeks of activities)

**Review of Literature (5.6 ECTS)**
- Development a Framework to Assess National Spatial Data Infrastructures (2006)

**Writing of Project Proposal (4 ECTS)**
- Development a Framework to Assess National Spatial Data Infrastructure (2005)

**Laboratory Training and Working Visits (5.7 ECTS)**
- Spatial data infrastructure concepts; Melbourne University, Australia (2007)
- Spatial data infrastructure evaluation; GeoConnections, Ottawa, Canada (2008)

**Post-Graduate Courses (7 ECTS)**
- Socio-cultural field research methods; MGS (2006)
- Complexity in and between social and ecosystems; CERES/PE&RC (2007)

**Competence Strengthening / Skills Courses (3 ECTS)**
- Scientific writing; WGS (2007)
- Presentation skills; WGS (2008)
- Personal efficacy; WGS (2008)

**Discussion Groups / Local Seminars and Other Scientific Meetings (5.7 ECTS)**
- Spatial methods (2006-2008)
- Workshops on assessing spatial data infrastructures; Wageningen, the Netherlands (2006/2007)

**PE&RC Annual Meetings, Seminars and the PE&RC Weekend (1.2 ECTS)**
- Introduction weekend (2006)
- PE&RC Day seminar (2008)

**International Symposia, Workshops and Conferences (10 ECTS)**
- Global Spatial Data Infrastructures-9, Santiago, Chile (2006)
- 13th EC GI&GIS Workshop, Porto, Portugal (2007)
- INSPIRE Conference, Maribor, Slovenia (2008)
- Global Spatial Data Infrastructures-11, Rotterdam, the Netherlands (2009)

**Courses in Which the PhD Candidate Has Worked as a Teacher**

- Spatial Data Infrastructures GRS-21306; CGI; 80 days/ 2 years (2008/2009)
- GIMA Module 3; CGI; 3 days (2009)

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