Governance Dynamics of Spatial Data Infrastructures

Jaap-Willem Sjoukema

Propositions

1. Governance of a spatial data infrastructure is always unique.
(this thesis)
2. Spatial data infrastructures are complex adaptive systems because of their governance.
(this thesis)
3. Feedback loops are too slow in science.
4. Traditional solitary research is inefficient.
5. Data is an institutionally underdeveloped currency.
6. The COVID-19 pandemic taught the world adaptive governance.

Propositions belonging to the thesis, entitled

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Chapter 1

Introduction

1.1. Introduction

We live in the Information Age. Like the Stone Age or Iron Age, this is a reference to the key resource that shapes and transforms today's society and progress: information. '[S]ources of productivity and competitiveness for firms, regions, countries, depend, more than ever, on knowledge, information, and the technology of their processing, including the technology of management, and the management of technology' (Castells 1997, p.7). Knowledge and information both need data as foundation. The data pyramid (see Figure 1.1) contextualises this hierarchical relation between data, information, knowledge and wisdom: from data we retrieve information, from information we retrieve knowledge and from knowledge we retrieve wisdom (Rowley 2007).

Figure 1.1. The data, information, knowledge, wisdom (DIKW) or data pyramid (Rowley 2007).

In this age, possessing data and having access to it is of critical importance for virtually everyone. With the World Wide Web, this access has become globally available at a low cost. However, sharing data is not self-evident: *'Clearly, considering that data are an important asset of companies, they are very often not willing to share them with the rest of the world'* (Kotsev et al. 2020, p. 7). Even if an organisation is not unwilling to share its data, there are still barriers: Sharing data costs time and money and in many cases there is no incentive for sharing, as the sharing organisation already possesses the necessary information. This leads to the situation that similar data is acquired and possessed by multiple organisations, leading to data redundancy.

This is especially inefficient for data that is costly to obtain. Spatial data, also called geodata or geospatial data, is such data. The key feature of spatial data

is that it has a spatial reference to a location (GSDI 2004). As *'everything happens somewhere'*, this information is critical in many processes such as disaster management, environmental protection and urban planning (UN-GGIM 2018). In many cases, spatial data is difficult to share, as depending on its scale and level of detail, the datasets can be large and spatial data has its own technicalities (GSDI 2004; van den Brink et al. 2019; Lee and Kang 2015). To make spatial data sharing easier, the spatial data infrastructure (SDI) concept emerged from the 1990s (Masser 1999).

1.2. Spatial data infrastructures

A spatial data infrastructure (SDI) facilitates and coordinates spatial data sharing and exchange (Crompvoets et al. 2004). The term 'spatial data infrastructure' is interchangeable with the term 'geo-information infrastructure', although the former has become the most popular, especially in scientific literature (Groot 1997). Traditionally, SDIs are broken down in five core components: people, data, standards, access network and policy (see Figure 1.2). As people want to share or access spatial data, they have to go through the three other components: standards are necessary for interoperable data and web services, access network (or technology) is necessary for access to the location where the data is physically stored in order to use it and policy is needed to understand what you are allowed to do with the data (e.g. licensing) at what costs, but also to stimulate or even require data sharing and re-use (Rajabifard and Williamson 2001; Rajabifard, Feeney, and Williamson 2002).

Figure 1.2. Model of Rajabifard showing the five SDI components and their relation (Rajabifard and Williamson 2001).

1.2.1. Rise of the spatial data infrastructure

The SDI concept emerged from the 1990s and many governments and other organisations started to develop SDIs from then on. Especially the United States (US) executive order for a National Spatial Data Infrastructure (The White House 1994) is seen as an important milestone in SDI development and research. Although the first operational and successful SDIs were corporate SDIs, for example in the oil and gas industry (Groot 1997), the SDI concept gained especially momentum in the public sector on all kinds of governmental levels, such as the local (e.g. Gemeente Amsterdam 2021), regional (e.g. Informatie Vlaanderen 2021), national (e.g. PDOK 2021) and international level (e.g. European Commission 2021e).

This is not surprising considering the increased importance of information and the ‘agencification’ of public institutes from the 1980s onwards, which lead to a fragmentation of governmental information (Sjoukema, Bregt, and Cromptvoets 2017). As many governmental organisations needed the same data, but were busy with searching, acquiring and negotiating data access, the goal of many governmental SDIs such as the one from the US was on avoiding data duplication and more effective use of governmental resources (The White House 1994).

From the 2000s onwards, the goals and visions on SDIs changed. Where the first generation of SDIs had a high focus on data integration, the second generation has a larger focus on data dissemination towards users (Rajabifard et al. 2003; Hendriks, Dessers, and van Hootegem 2012). Also, a third generation of SDIs has been distinguished which puts users even more central in the SDI development (Hennig and Belgui 2011).

This evolutionary trajectory was necessary as SDIs were not very successful from the start: there was a high focus on standards, technology and policies, while SDI use remained low during the first and second generation (Budhathoki, Bruce, and Nedovic-Budic 2008). The fact that SDIs are complex and evolve over time causes that SDIs are also considered to be complex adaptive systems (CAS) (De Man 2006; Grus, Cromptvoets, and Bregt 2010). Complex adaptive systems adapt and self-organise due to their many interactions and feedback loops. Although complex adaptive systems are sensitive to their initial conditions (path-dependent), their dynamics are nonlinear and unpredictable. This is partly due to its internal adaptive behaviour but also because its openness to the environment and external events which can influence the trajectory of a

complex adaptive system considerably (Grus, Cromptvoets, and Bregt 2010; Duit and Galaz 2008).

1.2.2. Open Spatial Data Infrastructures

An external development which did influence SDIs considerably, is the open government movement. Open standards from the Open Geospatial Consortium (OGC) have resulted in many standards for exchanging and disseminating spatial data. With open source software tooling such as Mapserver, Geonetwork and OpenLayers, hosting, servicing and viewing spatial data and metadata became much easier (Steiniger and Hunter 2012). And through open data, spatial data became openly accessible for everyone under open licensing such as Creative Commons (Welle Donker 2016).

Although these open concepts were not new, the transformation towards open SDIs was boosted considerably when open data became advocated or even required by many governments, such as the European Union (European Parliament 2003), the United States (Obama 2009) and United Kingdom (Geographic Information Panel 2008). In accordance with these policies, many SDIs switched to providing open data, although their actual openness may vary from SDI to SDI (Vancauwenberghe et al. 2018; Vancauwenberghe and van Loenen 2018).

Open data resulted in a tremendous growth of spatial data use. For example, the use of web services from PDOK, the central distribution platform of the Dutch national spatial data infrastructure has grown from 1.1 billion hits in 2014 to 30.9 billion hits in 2020 (see Figure 1.3 (PDOK 2021)). A Danish study on the economic impact of open spatial data in Denmark estimates that the socio-economic value of open geodata grew from 1.6 in 2012 to 3.5 billion Danish krone in 2016 (PricewaterhouseCoopers 2017). Also in the Netherlands, multiple studies prove a positive result of opening up spatial data such as an overall higher data quality, more use, new user groups, more feedback and a very positive societal cost-benefit ratio (Bregt et al. 2013; Bregt et al. 2016; Welle Donker, van Loenen, and Korthals Altes 2017).

1.2.3. Current challenges

But this success has also a flip side: with growing SDI use, SDI providers struggle with growing SDI costs. Traditional business models for funding spatial data

Figure 1.3. Graph showing the yearly growth of use of PDOK, the Dutch national spatial data infrastructure (PDOK 2021).

become obsolete, which makes SDIs and their spatial data more dependent on central funding (Welle Donker 2009). Currently, in the Netherlands, there are plans by the central government to restrict unlimited free access to key spatial data sets, by letting users pay by high volume usage (Ollongren 2020). These plans lead to resistance by spatial data users, such as local governments (Geluk 2020). Furthermore, especially at the start, open data has also brought tensions between governments and the private sector (e.g. court procedures such as *Gerechtshof Den Haag* 2014).

As SDIs are digital infrastructures, they also have to respond to the rapid innovations in technology and standards. Standards for discovering, accessing and exchanging spatial data have been well developed in the past, but currently the notion exists that these developments were too much unconnected with the ‘mainstream’ web developments. To bridge this gap, multiple standards are now developed for providing spatial data through linked data and REST API’s (van den Brink et al. 2019). Furthermore, spatial data seems to get bigger and more dynamic (e.g. real-time) as more and more sensors are deployed. New technologies for accessing, storing and analysing spatial data such as cloud computing are therefore inevitable (Lee and Kang 2015).

SDI use is not only growing and becoming more diverse, also the role users may play in SDIs changes. Developing and collecting spatial data is not only for geo-

information experts anymore. Citizens have become willingly and unwillingly sensors for spatial data (Goodchild 2007). A good example of volunteered spatial data collection, also known as volunteered geographic information (VGI), is OpenStreetMap, which resulted in a highly detailed map of the world, based on voluntarily efforts. Budhathoki et al. (2008) therefore not only speaks of spatial data users and producers, but also 'producers', referencing to the mixture of these roles. But despite these changing roles and their announced role in the third generation SDIs (Budhathoki, Bruce, and Nedovic-Budic 2008; Hennig and Belgui 2011), true incorporation of these new roles around traditional SDIs seems so far limited.

To summarise, we witness that every SDI component as distinguished in Figure 1.2 is highly dynamic and brings their own challenges. As SDIs are more than the sum of their parts, this brings especially challenges for decision makers on SDIs on how to properly govern an SDI from a holistic point of view. This raises the question on how to successfully organise the governance of SDIs, despite their dynamics and complexity. But before we dive deeper in SDI governance, we first take a look at the concept of 'governance' itself.

1.3. Governance

Governance is a word with many interpretations. *'It appears in almost as many versions as there are authors writing about it'* (Pollitt and Bouckaert 2011, p. 21). It is striking that both in science and practice the term 'governance' has become extremely popular, while there seems no common definition on what governance exactly is. This can easily lead to misunderstandings (Robichau 2011). For example, in practice governance seems to refer in many cases to the formal structures on how interorganisational cooperation is organised and their institutions (see for example UN-GGIM 2018, p. 21). While from a scientific perspective, governance is mostly viewed as a dynamic and interactive process. However, also in scientific literature, notions and ideas on governance are continuously shifting.

1.3.1 Evolution of governance

Like SDIs, governance emerged from the 1990s as a new perspective on governing and government. Since the 1960s these perspectives are shifting (see table 1.1). A first shift was in the 1960s towards what is called the 'golden age of planning'. In this period, decisions were rational and based on science

and expertise. A new view was introduced in the late 1970s/early 1980s: governmental organisations were deemed too large and bureaucratic and had to behave more like businesses. This period, which was named ‘new public management’ (NPM), led to a large focus on efficiency. Large bureaucracies were split up in smaller agencies (‘agencification’) in order to behave like competing business. Many former governmental tasks were outsourced or privatised: a focus on less ‘rowing’ and more ‘steering’ (Pollitt and Bouckaert 2011).

From the 1990s until now, the concept of governance emerged. Although interpretations on governance vary, many scholars agree that governance emerged from a network perspective on governing (e.g. Rhodes 1996; Kersbergen and Waarden 2004; Pollitt and Bouckaert 2011). In these networks, which may be self-organising, also citizens, private organisations and non-governmental organisations (NGOs) are active. Therefore, governance may be seen as a more inclusive concept than a focus on ‘government’ alone (Pollitt and Bouckaert 2011).

It is important to understand that although from a distance there seems to be clear shifts in theories on governing, these are more evolutions than revolutions. Governance did not replace the hierarchical or market-driven notions of the past, but added an extra layer to it (Pollitt and Bouckaert 2011). Governance is still evolving and new notions on governance are still introduced in science and practice, such as for example data driven policymaking and governance (Esty and Rushing 2007). These changes in the normative perspective on governance are also called meta-governance or third-order governance (Kooiman 2003).

Table 1.1 Table summarising the main shifts in governing over the past decades.
Adapted from Pollitt and Bouckaert (2011).

Period	Name	Characteristics
Mid 1960s to late 1970s	Golden age of planning	Rational, hierarchical planning and cost-benefit analysis. Science and expertise will produce progress.
Late 1970s to late 1990s	New public management	Business & management techniques to improve efficiency. Disaggregation of bureaucracies, privatisation, key performance indicators.
Late 1990s to now	Rise of ‘governance’	No dominant model, but focus on networks, self-organisation, co-modes of governing, public value, transparency and trust.

Next to meta-governance or third-order governance, there are two other levels: First- and second-order governance. First-order governance refers to the day-to-day governance aimed at problem solving and opportunity creation. Second-order governance focusses on changing and improving the structures or institutions which bind the first-order governance (Kooiman 2003). All governance orders have their own dynamics, although their temporal scales vary.

1.3.2. Governance in this thesis

Even though governance comes in many forms and definitions, there seems a common understanding that it consists of three main ingredients:

1. Actors (or stakeholders)
2. Structures (or institutions, rules)
3. Interactions (or steering mechanisms, instruments)

In this research, governance is referred to as the governing process in which multiple actors, both public and private, can influence this process through interactions which are bound by the formal and informal structures, which enable and constrain this governing process. These structures are stable in the short term and beyond control of one actor, but can be changed in the long term (Kooiman 2003; Giddens 1984).

This holistic perspective on governance is largely derived from the theoretical conceptions of Kooiman (2003). Kooiman was one of the first scholars who brought governance and the changing government-society interactions to the spotlight (Kooiman 1993). His socio-cybernetic and systems perspective on governance (Rhodes 1996) fits well the complex adaptive systems perspective on SDIs.

1.3.3. Governance of complex adaptive systems

Due to the many actors, actions and reactions, governance is a complex process. *'The often 'chaotic' nature of societal processes means that small incidents can have major consequences (the butterfly effect) and even non-action may develop – dynamically – into a crisis'* (Kooiman 2003, p. 63). Verhoest et al. (2007), also witness an *'action-reaction pattern in which the solution to a problem turns into a problem itself'* (Verhoest, Bouckaert, and Peters 2007, p. 330). Therefore, it is not surprising that due to these complex dynamics,

governance of complex adaptive systems is an extremely challenging subject.

In general, in governance literature three governance forms or modes are distinguished (e.g. Edelenbos et al. 2015):

- Hierarchical governance (or top-down governance)
- Network governance (or co-governance, horizontal governance)
- Self-governance (or self-steering/organising, bottom-up governance)

Each of these governance forms has its advantage in dealing with dynamics and complexity. Kooiman (2003) hypothesises that self-governance can cope with dynamics the best, while network governance performs medium and hierarchical governance the lowest in dealing with dynamics. However, hierarchical governance can cope with complexity the best, while network and self-governance perform low with complexity (Kooiman 2003). According to Pierre & Peters (2005), central hierarchical forms of governance have the issue that information and feedback flows poorly through the system, while decentral governance forms have the issue of information deficiency (Pierre and Peters 2005; Duit and Galaz 2008).

Therefore, there does not seem to be an optimal form of governance to cope with complexity and dynamics. What matters more is the adaptive capacity of governance, which requires a mixture of governance forms (Edelenbos et al. 2015; Dietz, Ostrom, and Stern 2003). Furthermore, by involving a large and diverse group of stakeholders, key information can flow more easily. By nesting institutional arrangements in complex and redundant layers, also more flexibility in structures can be achieved (Dietz, Ostrom, and Stern 2003). However, one must also acknowledge there is a '*fundamental tension between institutional stability and flexibility*' (Duit and Galaz 2008, p.329). Indeed, governing complex and dynamic systems seems to require a complex form of governance.

1.4. SDI Governance research challenges

Currently, rather little is known about the complex and dynamic behaviour of SDIs and SDI governance. In recent years, SDI governance accumulated more research interest (e.g. Box and Rajabifard 2009; Vancauwenberghe 2013; Cromptvoets et al. 2018; Vancauwenberghe and van Loenen 2017). However, in many cases, these studies analyse SDI governance at a fixed moment or for a short period of time, which makes it difficult to unravel the temporal dynamics

of SDI governance.

The notion that SDIs behave like complex adaptive systems (De Man 2006; Grus, Crompvoets, and Bregt 2010) is embraced in the field of SDI science. There are multiple examples of studies which try new methods and techniques to better understand this behaviour such as through system dynamics modelling (Mansourian and Abdolmajidi 2011; Mansourian et al. 2015), press-pulse dynamics (Gourmelon et al. 2019), agent-based modelling (Lubida et al. 2020), social network analysis (Vandenbroucke et al. 2009; Georis-Creuseveau, Claramunt, and Gourmelon 2017) and stakeholder analysis (Coetzee et al. 2018; Coetzee et al. 2019). Furthermore, there are a few longitudinal case studies available such as from Koerten (2011) which describes SDI development dynamics in detail. However, in most cases, these studies only describe partial aspects of SDI governance. An overarching framework to better understand the governance dynamics of SDIs is missing.

Meanwhile, in practice, SDI practitioners struggle with SDI governance. This struggle is not surprising as decision makers are confronted continuously with new developments on for example technology (Tripathi, Agrawal, and Gupta 2020), standards (van den Brink et al. 2019), data (Lee and Kang 2015) and policies (Esty and Rushing 2007). Furthermore, the group of SDI stakeholders is growing (Vancauwenberghe and van Loenen 2017) while SDI funding is under pressure (Welle Donker 2009). Given these continuous dynamics, which may be partly context specific, it seems impossible to develop a static golden recipe which will improve SDI governance globally. Therefore, this research will focus on understanding the governance dynamics of SDIs and to develop tools which will provide insights in SDI governance for both science and practice.

1.5. Research objectives

The objective of this research is to analyse SDI governance dynamics and to develop tools in order to gain insights in current SDI governance and their possible future. To fulfil this objective, we first need a better understanding of the adaptive behaviour of SDIs and their governance by studying the past. From the past, we can learn what works and what does not work. Therefore, we need to study the governance of SDI cases with a long history over a longitudinal time horizon. By combining this analysis with knowledge derived from literature on SDI governance, we can distinguish a framework to evaluate the strong and

weak governance aspects of an SDI case.

1 Next to this inductive and deductive approach, simulation is often referred to as a third way of doing science (Axelrod 1997). By developing an agent-based model to simulate SDI governance dynamics, it becomes not only possible to examine the dynamics from the simulations, but also to ask 'what if' questions for its future. By applying these developed methods on an actual SDI case, we can prove the value of these tools for gaining insights in SDI governance and their possible future.

To summarise this research has the following four goals:

1. Analyse the adaptive behaviour of SDI governance
2. Develop a framework to evaluate SDI governance dynamics
3. Develop an agent-based model to simulate and examine SDI governance dynamics
4. Evaluate the current governance state of an SDI and explore future governance scenarios with the developed methods

1.6. Thesis outline

Figure 1.4 shows how this research is structured in order to fulfil these objectives.

Chapter 2 will explore how SDIs and their governance evolve and adapt by looking at the development of the large-scale base maps in the Netherlands and Flanders (Belgium). As both are similar products with similar end goals but in different contexts, comparing their governance dynamics will be insightful for a better understanding of the adaptive behaviour of SDI governance.

Chapter 3 also looks at the development of two other SDI cases, but these cases are selected as they experienced issues in their governance. Both cases, the Risk map (Risicokaart) and New Map of the Netherlands (Nieuwe Kaart van Nederland), were early adopters of SDI technology and standards. However, after a decade, both SDIs entered a crisis period and the New Map of the Netherlands even stopped. This chapter proposes a framework to evaluate the governing system of SDIs and describes how the crisis periods of these cases transformed this system.

In chapter 4 we use the findings on SDI governance dynamics and try to simulate these with agent-based modelling. Through agent-based modelling it is possible

Figure 1.4 Structure of this thesis.

to simulate the dynamics of complex adaptive systems. This chapter describes the model set-up and its results. To verify if the model is a valuable approach for exploring SDI governance, we consulted multiple SDI experts.

Chapter 5 takes the governing system framework of chapter 3 and the agent-based model from chapter 4 and applies these methods on INSPIRE, the European spatial data infrastructure. The INSPIRE directive requires all European Union (EU) member states to provide webservices of harmonised data through their own SDI. As the implementation phase of INSPIRE ends in 2021, this is a critical moment to evaluate its European governance and propose recommendations for its future. With the two instruments developed in chapter 3 and 4, we were able to do this.

Chapter 6 concludes this thesis and puts the findings in a broader perspective. What did we learn? What does this mean for SDIs and governance? And what are new questions to explore in future research?

Chapter 2

Evolving Spatial Data Infrastructures and the Role of Adaptive Governance

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Abstract

Spatial data infrastructures (SDIs) are becoming more mature worldwide. However, despite this growing maturity, longitudinal research on the governance of SDIs is rare. The current research examines the governance history of two SDIs in the Netherlands and Flanders (Belgium). Both represent decades-long undertakings to create a large-scale base map. During these processes, SDI governance changed, often quite radically. We analyse written accounts from geo-information industry magazines to determine if the SDI governance of these two base maps can be considered adaptive. We conclude that SDI governance was adaptive, as it changed considerably during the evolution of the two SDIs. However, we also find that most governance models did not hold up very long, as they were either not meeting their goals, were not satisfying all stakeholders or were not in alignment with new visions and ideas. In recent years, the policy instruments governing these base maps became increasingly diverse. In particular, more hierarchical instruments were introduced. Indeed, governance scholars increasingly agree that governance can better respond to changes when a broader mix of policy instruments is applied. Alas, this does not make SDI governance any less complex.

Keywords: spatial data infrastructure; SDI; governance; SDI development; self-organisation; complex adaptive systems; longitudinal analysis; large-scale base map; the Netherlands; Flanders.

2.1. Introduction

2.1.1. Spatial Data Infrastructures

Spatial data infrastructures (SDIs) are becoming more mature worldwide. Their growing importance, increased connectivity and the greater participation of different public and private stakeholders have made appropriate governance essential for effective SDI development and management (Macharis and Crompvoets 2014). This is a challenge, however, due to the complex, multi-stakeholder, multi-level, technical and open nature of SDIs. As SDIs play an increasing role in society, more insight is needed into SDI governance.

In the Netherlands, Belgium and elsewhere, the governance of SDIs now often appears to be a matter of trial and error (Vancauwenberghe 2013). Hardly any evidence-based research exists on the effect of potential governance interventions, such as open data policy, changes in funding and coordination structures and participation of the private sector, on SDI effectiveness and efficiency. Formerly weak SDI components, such as standards, technology and data, have significantly improved over the years (Bregt and Crompvoets 2000; Bregt 2006). SDI governance might well be the “weakest link” in SDIs today.

A challenge in researching the relation between governance and SDIs is that ideas about both governance and SDIs are not stationary but change over time, place, culture and even discipline. This becomes clear in efforts to define these subjects, as there is a multitude of governance (Robichau 2011; Pollitt and Bouckaert 2011) and SDI definitions (Vandenbroucke et al. 2009; Hendriks, Dessers, and van Hootegem 2012). How we think of governance or SDIs today could be very different from how we view these subjects in the future. This makes planning for future-proof SDI governance a challenge.

Though academia has no agreed governance definition (Robichau 2011; Pollitt and Bouckaert 2011), we use a holistic meaning in this research. We do not distinguish between ‘hard government’ and ‘soft governance’ (Mörth 2009). Rather, we view all processes and structures for steering and managing SDIs as part of SDI governance (Rijke et al. 2012). These processes and structures can be governmentally or non-governmentally driven and can emerge from authoritarian (Fukuyama 2013), bottom-up or self-organising initiatives (Coetsee and Wolff-Piggott 2015).

Kooiman (2003) defines governance as follow: *‘Governing can be considered as the totality of interactions, in which public as well as private actors participate...; attending to the institutions as contexts for these governing interactions; and establishing a normative foundation for all those activities. Governance can be seen as the totality of theoretical conceptions on governing’* (p.4).

2 From this definition, we can distinguish three vital governance ingredients: ‘actors’ (public and private); ‘institutions’ (providing context and a foundation) and ‘interactions’. In our holistic approach, these actors can be anyone. Institutions can be formal, such as laws and policies, or informal, such as culture, values and beliefs. Interactions can both be deliberate, such as hierarchical steering mechanisms or coincidental. Governance as a totality is more than the sum of these parts.

In this respect, SDIs resemble governance. Rajabifard et al. (2002) define SDIs as made up of five components: ‘people’, ‘policy’, ‘standards’, ‘data’ and ‘access network’ (or ‘technology’). As the sum of these interacting parts, the SDI itself is bigger than just the parts alone. This is also one of the features of complex adaptive systems (Grus, Crompvoets, and Bregt 2010). Each SDI component, the interactions between them, as well as the SDI itself (‘the sum of the parts’) are in need of governance. It is therefore unsurprising that SDI governance is an incredibly complex subject that puzzles academics and practitioners alike. The current research, therefore, focuses on the evolutionary trajectory of SDI governance in the past, in the expectation that this might provide guidance for the future.

2.1.2. Global Governance Trends and the Evolution of SDIs

The concepts of governance and SDIs are continuously on the move, which only adds to their complexity. Within the governance domain, Verhoest et al. (2007) observe *‘an action–reaction pattern in which the solution to a problem turns into a problem itself’* (Verhoest, Bouckaert, and Peters 2007, p.330). New solutions are proposed to deal with unintentionally created problems, and so a continuous pattern of improvement emerges. The same action–reaction pattern can be observed within the SDI domain.

Grus et al. (2010) argue that SDIs can be seen as ‘complex adaptive systems’. Adaptability, in fact, is considered a foremost SDI feature: *‘A high degree of adaptability guarantees that an SDI can continuously develop by adjusting its*

structure, behaviour and goals to changing external circumstances' (Grus, Cromptvoets, and Bregt 2010, p.457). Key features of complex adaptive systems are their unpredictability and self-organisation, which are influenced by external factors due to their openness and internal factors like their history (path-dependency).

Interestingly, governance developments appear to have partly shaped the preconditions for the development of SDIs. From the late 1970s, governance entered a transition phase from the 'golden age of planning', in which science and experts determined rationally and hierarchically the way to move forward, into a governance paradigm now widely known as 'New Public Management' (NPM). NPM stresses running governments like a business in order to save on costs and improve efficiency and effectiveness. Implementation of NPM strategies has varied widely, but NPM trends were certainly recognisable in the 1980s and 1990s in many western countries (Pollitt and Bouckaert 2011). Hood (1995) identifies several dimensions of change introduced by NPM, such as disaggregation and specialisation of public organisations, more competition, use of corporate management practices and a focus on measurable outputs and performance.

The US executive order issued in 1994 by then-president Bill Clinton for a '*coordinated National Spatial Data Infrastructure*' (The White House 1994, p.1) marks for many academics and practitioners the official launching point for SDIs (e.g. Rajabifard and Williamson 2001; Masser 1999). The goal of the broader 'National Performance Review' policy in which it was embedded was '*a government that works better and costs less*' (Gore 1994). This focus on performance and efficiency suggests that the order was inspired by NPM ideals.

Although the foundation of the US national spatial data infrastructure (NSDI) seems to rest on an NPM basis, the goal of the NSDI was actually to counterbalance NPM symptoms. As NPM advocated disaggregation of large bureaucracies into small specialised and competitive organisations (also known as 'agencification'), it led inevitably to fragmentation of governmental information (Verhoest, Bouckaert, and Peters 2007). Therefore, the US NSDI initiative sought to create cross-agency coordination, '*to avoid wasteful duplication of effort and promote effective and economical management of resources by Federal, State, local, and tribal governments*' (The White House 1994; Gore 1994).

Rajabifard et al. (2003) observe a change in focus in SDI development around the start of 2000, which they call '*the second generation of National SDI initiatives*' (Rajabifard et al. 2003, p.103). An important aspect of this SDI generation is a shift in emphasis from data integration to data dissemination by creating a link between data and data users. By making people an important component of an SDI, the value of the SDI increases. This realisation by SDI practitioners is an important aspect of what Rajabifard et al. (2002) identify as a move away from product-based SDIs to process-based SDIs. Reasons for implementing an SDI changed from resource savings and increased productivity to the more holistic socio-cultural ideal of an SDI serving the interests of society as a whole (Rajabifard et al. 2003; Cromptoets et al. 2004).

Probably not coincidentally, ideas about governance also changed around the 2000s. While there seems no leading governance strategy such as NPM anymore, there is a general consensus that most western countries have moved away from a market perspective towards a network perspective on governance (Pollitt and Bouckaert 2011). Indeed, in trying to achieve cross-agency coordination, it became apparent that the state is not unitary, but plural, and that not competition, but networks and relations are important for coordination. These insights can be seen as the core elements of New Public Governance (NPG), which is cautiously identified as NPM's successor (Osborne 2010). While the NPG term itself is not embraced by all academics, the importance of network type mechanisms for coordination, next to market type mechanisms and hierarchy type mechanisms, is generally accepted (Verhoest, Bouckaert, and Peters 2007).

In the 2000s, 'trust' and 'transparency' also became important notions within many public administrations, leading to the 'open government' concept. Freedom of information is here deemed important for increasing accountability, trust and public participation, which are seen as lubricants of the democratic process (Worthy 2010; Pollitt and Bouckaert 2011).

The open government concept is clearly visible within the SDI domain: concepts such as 'open standards', 'open source software' and 'open data' were already coined, but now became advocated by many governments (e.g. the European Union (European Parliament 2003) and UK (Geographic Information Panel 2008)). Open spatial data has resulted in growth in usage of spatial datasets (Hansen, Hvingel, and Schröder 2013; Bregt et al. 2013), but also put pressure

on data financing models (Welle Donker 2009).

The changing governance paradigms seem clearly interrelated with the evolution of SDIs. However, it would be inappropriate to think of these governance paradigms as the only agenda-setting factor. Of course, the emergence of information and communication technology (ICT) was particularly determinative in SDI evolution. Many scholars (Rajabifard, Feeney, and Williamson 2002; Masser 1999; Maguire and Longley 2005; Koerten 2011) note a technology push in SDI development. Without technology, an SDI would not be feasible. Even governance paradigms such as 'open government' are linked to ICT advancements such as the Internet (Sanz 2014).

Furthermore, the question arises as to why SDI developments fit the governance paradigms so well. Are they determined by these paradigms, or are SDI developments framed into these paradigms in order to gain budget and support? Again, given the complex adaptive nature of SDIs, the answer could be both. In order to better understand SDI evolution, a closer look is needed at SDI governance itself.

2.1.3. SDI Governance Dynamics

SDI governance is clearly a main driver of SDI advancements, as it delivers in most cases the decisions and budgets needed for development. However, the way SDI governance has evolved and set the development direction of SDIs has not yet been studied in any detail. There appears to be various ways in which SDIs could come to life. Masser (1999) distinguishes two groups in his description of the first SDI generation: *'those which are the result of a formal mandate from government and those which have largely grown out of existing geographical information coordination activities'* (Masser 1999, p.75). Coetzee and Wolff-Piggott (2015) find, based on the SDI literature, that *'SDIs are evolving from top-down, centralized government funded initiatives into decentralized and bottom-up initiatives, but most SDIs are not yet self-organizing and user-driven systems'* (Coetzee and Wolff-Piggott 2015, p.124). Lance et al. (2009) conclude that in recent years more hierarchy has been introduced in the SDIs of Canada and the USA: *'Hierarchical controls may facilitate coordination to an extent that autonomy-seeking public managers need not automatically disparage such intervention; in fact, they may seek it'* (Lance, Georgiadou, and Bregt 2009, p.265).

These two conclusions may seem contradictory, but could both be valid for specific SDI cases, given SDIs' complex, adaptive and path-dependent nature (Grus, Cromptoets, and Bregt 2010). The question is can we qualify SDI governance as adaptive, and how does SDI governance evolve over time.

To answer this question, we assessed the governance evolution of two SDI cases: the Grootchalige Referentiebestand (GRB) of Flanders, Belgium, and the Basisregistratie Grootchalige Topografie (BGT) of the Netherlands. Both are large-scale base maps with all SDI components in place; that is, data, standards, technologies, policies and stakeholders. In both cases, standardised spatial data is collected by companies or governments, put into a central and authoritative database and disseminated via the web to users. This is all supported by an organisational and technical infrastructure. These cases also have very similar goals and objectives, resulting in similar products. However, their history, organisation and governance are very dissimilar. A key reason to choose these cases was their relatively long histories, as the BGT dates back to 1971. Each case will be further described in Section 2.3, after presentation of the data and research methods in Section 2.2. Section 2.3 then delves deeper into the SDI cases, tracing their histories and then synthesising and comparing the two. Section 2.4 discusses the results of our analysis, and Section 2.5 presents conclusions.

2.2. Methods, Data and Cases

2.2.1. Data Collection

The study of SDI governance dynamics could be approached using various methodologies, such as interviews, analysis of official documents and surveys. For our purpose of studying the long-term evolution of SDI governance, interviews and surveys were deemed less suitable, as memories can be altered, consciously or unconsciously. Instead, we chose to use written documents, as documents can be considered 'unobtrusive', 'non-reactive' and 'stable' (Bowen 2009) and are therefore suitable for longitudinal analysis (Bryman 2012, p. 304). We used articles from geo-information and geodetic industry magazines. The benefit of using these magazines is that they are not owned by a specific party and therefore provide a platform for both SDI proponents and critics.

Six Dutch geo-information magazines were selected as research material: *Nationaal Geodetisch Tijdschrift (NGT)*, *Geodesia*, *Geo-info*, *Vi-Matrix*,

GeoInside and *GeoPlatform* (Table 2.1). The first three were digitally available via an online web archive. The magazines that also covered developments in Flanders (*Vi-Matrix*, *GeoPlatform* and *GeoInside*) had to be manually checked and scanned.

Scott (1990) proposes four quality control criteria for assessing documentary sources: authenticity, credibility, representativeness and meaning. As we retrieved the magazines directly from the publisher, the documents' authenticity was a given. The credibility of the articles was ensured because major events were in most cases referenced in multiple articles. Furthermore, reactions or rectifications could be expected when authors or editors made a mistake or readers disagreed. As the articles were written in clear Dutch, and the researchers were native speakers of Dutch, there was no difficulty in identifying the meaning of each article, though of course there is always a risk of misinterpretation. We used the total population of available articles, so we can qualify the documents as representative. However, we must note that important governance developments, such as backroom politics, could have remained hidden from this research if they were not referenced in published accounts.

Although the coverage of the magazines was good, especially in the Netherlands, their frequency of appearance had recently diminished. In Flanders, coverage was sparser; the region-specific magazines even stopped publishing in 2013. Moreover, these magazines started a few years after the first large-scale base map developments. Luckily, later articles referred to the starting period, enabling us to form a picture from these secondary sources. As there is often a delay between an event happening and an account of it being published, this method

Table 2.1. Overview of the Dutch geo-information magazines used as research materials.

Magazine	Active Period	Coverage
<i>Nationaal Geodetisch Tijdschrift (NGT)</i>	1971–1979	The Netherlands
<i>Geodesia</i>	1959–2003	The Netherlands
<i>Geo-info</i>	2004–now	The Netherlands
<i>Vi-Matrix</i>	1993–2010	The Netherlands and Flanders ¹
<i>GeoInside</i>	2011–2013	The Netherlands
<i>GeoPlatform Vlaanderen</i>	2006–2013	Flanders

¹ *Vi-Matrix* described geo-information developments in Flanders until 2006, then *GeoPlatform* took over.

was in effect used on multiple occasions.

As there was no active reporting on Flemish activities in geo-information (GI) magazines from 2013 and later, supplementary interviews were held with two staff members of 'Informatie Vlaanderen' (Information Flanders), which is the current e-government organisation for Flanders. Both staff members were policy advisors on the governance of the Flemish e-government structure, which also included the GRB. The interviews were unstructured. Questions were asked about the establishment of 'Information Flanders' and the current and future governance of the organisation. Because there were still magazines active in the Netherlands, interviews were not necessary to supplement data collection there.

Articles concerning the Dutch large-scale base map (BGT) were found by searching for keywords such as 'GBKN' (Grootchalige BasisKaart Nederland), 'BGT', 'Grootchalige BasisKaart' and 'GBK'. These represent either the name or abbreviation of the current large-scale base map or its predecessors. All articles containing these keywords were selected; only advertisements were ignored. In a similar fashion, articles related to the Flemish large-scale reference map (GRB) were selected by searching for the keywords 'GRB' or 'Cardib'. Because these articles were selected manually, the magazines were double-checked. In total, 877 articles were selected covering the history of the BGT and 176 covering the history of the GRB. Figure 2.1a,b show the distribution of the articles over time.

2.2.2. Data Analysis

First, the articles were analysed at the meta level. For all articles, the title, publication date, page numbers, article type, authors and author organisations were noted. The author organisations were further aggregated into several higher stakeholder abstraction categories to assess whether the overall picture was overly distorted by one stakeholder group. These categories, in most instances, were naturally formed, based on the stakeholders represented in the articles. For example, all utility companies were categorised as 'utility', and all government entities, except central government organisations, were grouped in the 'local government' category. Organisations that were not aggregated were the Dutch 'Cadastre' for the BGT case and 'AGIV' (Agency for Geo-Information Flanders) for the GRB case, as these organisations were highly involved in the

Figure 2.1. Distribution of found magazine articles over time: (a) distribution of articles containing BGT-related keywords (Netherlands); (b) distribution of articles containing GRB-related keywords (Flanders).

creation of the large-scale maps (see Section 2.3).

Associations and foundations were aggregated into three categories: 'associations', 'interest groups' and 'partnerships'. The category 'partnerships' includes official collaborations in which organisations worked closely together (or even joined up) to achieve their common goals. 'Interest groups' consist of lobby organisations for governmental organisations or private companies. 'Associations' comprise geo-information or geodetic associations for knowledge sharing.

Articles written by multiple authors from different stakeholder categories were classified as 'mixed'. Figure 2.2a,b present relative distributions of the author affiliations aggregated into case-specific stakeholder categories.

It should be noted that the GRB-related articles were much more likely to be written by reporters and editors, as these magazines had a more journalistic character. Furthermore, the division seems balanced, as certain increases or decreases of particular stakeholder categories can be explained by the development of the SDI (described in Section 2.3).

Following the meta-analysis, the titles and content of articles were scanned and read in-depth if they contained organisational information on the SDI. This information provided the basis of the case descriptions, while simultaneously providing a window for the study of the SDI governance evolution in each case. To make the analysis transparent, references were documented in the case descriptions (Section 2.3). These refer to the list of articles used in Appendix A.

We then synthesised and compared our findings from the cases. Our analysis focused on two governance ingredients: actors and interactions. As stated in the introduction, institutions, both formal and informal, are also an important governance ingredient. However, informal institutions, such as cultures, values and beliefs, proved particularly difficult to distinguish from the magazine articles. Findings on formal institutions, such as laws, policies and organisations, are covered in the sections on interactions and actors.

Figure 2.2. Relative distribution of article author affiliations, categorised into case-specific SDI groupings per decade: **(a)** distribution of BGT-related articles (Netherlands); **(b)** distribution of GRB-related articles (Flanders).

2.3. Results

2.3.1. The Netherlands: Key Registry Large-Scale Topography (BGT)

The history of the Netherlands' Key Registry Large-Scale Topography (BGT) dates back to the early 1970s. In 1971, a commission of scientists, governments and utility companies investigated the need for a uniform cable and pipe registration system (1971a). The conclusions of that study yielded a new commission, which studied the need for a uniform large-scale base map that could also serve as a reference map for the cable and pipe registry (1971b; 1972a; 1972b). In 1974, the report of this second commission was released, deeming the uniform base map feasible (1973a; 1974a). The commission made several proposals for realisation, suggesting among other things standards, techniques, stakeholders and a governance framework (1973a; 1973b; 1973c; 1974a). Although there were votes to create this map digitally (1973d; 1973e; 1973f), the maps and its production were ultimately analogue-based.

As often seen during the 'golden age of planning' (Pollitt and Bouckaert 2011), the advice of the experts and scientists was followed. In 1975, a Royal Decree launched the creation of the Grootchalige Basiskaart Nederland (GBKN; 'Large-Scale Base Map of the Netherlands') (1975a; 1975b). As proposed in the commission report, the Ministry of Housing and Spatial Planning gave the Dutch Cadastre the task of creating the map. The Central Mapping Board was officially installed in 1976, made up of stakeholders including utility companies, local government, the Cadastre, topographic bodies and ministries (1976a; 1976b). The goal of this Board was to determine priorities, allocate funds and develop standards and techniques (1974a; 1975a; 1975b; 1976a; 1976b). Provincial mapping boards, coordinated by the regional bodies of the Cadastre, were to facilitate regional collaboration and provide input to the Central Mapping Board (1974a; 1978).

In 1975, the first GBKN project began (1976c; 1976d; 1977). However, with the exception of a few regions, map production did not go well (1980). The first governance intervention came in 1983. A government ICT report advised greater focus on regulation, instead of consultation. Furthermore, it recommended that the Ministry create an organisation that could coordinate and facilitate all geo-ICT developments: the Board for Property Information (RAVI). The Central Mapping Board objected to the report's conclusions, noting that consultation

remained crucial for such a big and expensive task (1983; 1984a; 1984b). The ministry listened: RAVI replaced the Central Mapping Board, but the original collaborative structure of the GBKN project remained at the level of the provincial mapping boards (1987a). Articles foreseeing further regulation were included in the preparation of a new Cadastre law (1985a).

Meanwhile, New Public Management (NPM) made its entrance. Government demanded that the Cadastre cover its own costs (1984c; 1984d; 1985b; 1989a). Budgets shrank (1986a), and local standards emerged to make the mapping feasible in regions where there were not enough partners (1986b). Criticism swelled from municipalities (1984d; 1989b; 1990a; 1990b) and the utility companies (1989c), as they considered the regional Cadastre offices as behaving too autonomously.

Around 1991, the Secretary of State of the Ministry of Spatial Planning and Environment intervened. The Cadastre's financial situation was poor and the Secretary of State demanded it make severe cuts (1991a). Creation of the GBKN was one of the reasons for the Cadastre's losses (1987b; 1988), and only 30% of the country was covered (1992b). The Ministry determined that the GBKN would no longer be a primary Cadastre task (1991b; 1992a). GBKN articles were scrapped from the Cadastre law in 1992 (1991c; 1992a; 1992c). The national government was no longer willing to participate in the GBKN (1992b).

This could have been the kill switch, but it was not. Regional public-private partnerships were formed to create and maintain the GBKN in the regions (1992b; 1992d). The Cadastre became a partner instead of a coordinator. The national government provided 10 million guilders (4.5 million euros) for better organisation and collaboration for the GBKN. A foundation was set up which would coordinate GBKN activities nationwide: the National Partnership GBKN (1992e; 1993a; 1993b; 1993d). The municipalities' position was strengthened, and as they could choose to either do the map production alone or operate in a public-private partnership mode (1993a). Moreover, a goal was set: the GBKN was to cover the entire country within 10 years (1993b; 1993c).

During the 1990s, GBKN production soared (1999a; 2000a). However, a fierce debate also emerged. The GBKN standard was line-oriented, for use in computer-aided design (CAD) systems, but users demanded object-oriented data, which worked better with geographical information systems (GIS) (1993e;

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1995a). An object-oriented GBKN was promulgated as a cure for the regional diversity in GBKN data (1995a; 1995b). After some years of feasibility research and discussion (1996a; 1996b; 1997a; 1997b; 1997c; 1997d), the National Partnership decided not to invest in this, but to focus instead on completion and other ways to standardise the product (1998). In 2001, the GBKN was finished (2001a). Now that the map was complete, the National Partnership repositioned itself (1999b; 2000b; 2003a; 2003b). Goals were set for updating and standardising the product, conducted by the regional partnerships (2000b; 2001b; 2001c).

Meanwhile, the concept of 'authentic registries' emerged in government policy in the Netherlands (2002a; 2002b). An 'authentic register', later called a 'key registry', is a registration system formally appointed by government with legally mandated quality standards for use by government. The National Partnership saw it as an important goal that the GBKN become a key registry, as this would provide it a clear legal status and organisational and financial framework, while acting as an accelerator for standardisation (2002c). Although several other governmental spatial datasets were already considered 'key registries', the GBKN had to wait (2002d; 2003c). After all, creating a uniform GBKN would be quite costly (2006b) and support from many organisations was needed (2003c).

During the ensuing years, some municipalities independently created their own object-oriented large-scale base maps (2002e; 2003d; 2003e). However, becoming a key registry remained an important motivator for these organisations to join the National Partnership in its lobby (2003d; 2003e; 2003f). After an exploratory phase (2006a) and successful budget claim in 2008 (2009a), the mandate was given by the national government to transform the GBKN into the Basisregistratie Grootschalige Topografie (BGT; 'Key Registry Large-Scale Topography').

In 2009, a declaration of intention was signed by all partners creating the object-oriented BGT standard (2010). Interestingly, although the Cadastre and utility companies had done much in the past to create the GBKN, the BGT was created by government organisations alone (2009a; 2009b). However, because of the decentral organisation, some 450 governmental organisations were involved (2011; 2012a). The Cadastre was to continue to maintain the central database (2012b) and the National Partnership GBKN was transformed into the Partnership of BGT Key Registry Holders (2012c). Because key registries were

created by government and because the BGT was declared open data, public utility companies no longer had to invest in the BGT (2009a; 2012a). However, as a main user, they did retain their position in steering groups (2009a).

In 2012, the BGT standard and law were finished (2013) and the key registry holders began to build the BGT (2014). The task was set for completion by the start of 2016 (2012a), but the second half of 2017 currently seems the likely completion time (Ministerie van Infrastructuur en Milieu 2017). Now that the BGT is almost finished, efforts are being made to improve cohesion of the BGT with other datasets within and between organisations (2017a; 2017b).

2.3.2. Flanders: The Large-Scale Reference Map (GRB)

The origin of the GRB is two-pronged. One prong can be traced to the 'Cardib' initiative. Cardib was a public-private partnership erected in 1990 by four small public utility companies with the goal of creating a large-scale base map of Flanders. Together with its Walloon counterpart, Bicard, Cardib had agreed that the company Bicardib would do the data creation (Bicardib fulfilled this role for both partnerships) (1993f). One of the company's founders and shareholders was Eurosense, which was considered a monopolist in aerial photography (1993f; 1993g).

Although some other public utilities joined, Cardib gained momentum in 1992, when it diminished the influence of Eurosense and two large private utility companies showed interest and joined (1993g; 1994a). At least three interested organisations in a region were needed to create a Cardib map (1994b). Although the initiative united some organisations, only 3.8% of Flanders was covered by a large-scale map at the start of 1997 (1997e). Another issue was that, despite agreements, these covered areas were not updated (1997f). This was reason for the two private companies to leave the initiative (1997f; 1997g). In 1999, the last Cardib project was finished and the initiative was declared bankrupt. 'GIS Flanders' took over all available data and aerial imagery (1999c).

GIS Flanders had started out at the end of the 1980s as a working group to study the GIS needs of federal government departments. It advised in 1991 putting in a huge order to Eurosense, to purchase aerial imagery for the whole Flanders region. This order was blocked, however, by the Financial Inspection department and later by the Flemish Parliament (1993g). GIS then became a politically sensitive issue and all investments were barred (Vlaamse Raad

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1992) (1993g; 1993h; 1994c). In 1993, after showing their dissatisfaction in local media, a group of GI professors was asked by the Flemish government to consult on the development of a Flemish spatial data infrastructure. The group designed a governance structure, with a technical centre, a geo-information board and a coordinating minister. It was to serve not only the federal level but interests at all administrative levels (1993i). After almost two years of meetings and negotiations (1994d; 1994e; 1994f; 1995c), the designed organisational structure was officially adopted in 1995 (1995d). The technical centre, now called 'Support Centre', expressed interest in joining the Cardib initiative (1997g), but, by the time it was fully operational, Cardib was defunct (1999c).

The Support Centre designed a new model for a large-scale base map: the Grootchalige Referentiebestand (GRB; 'Large-Scale Reference Map'). Feasibility was a key issue in the design choices for this map (1999d). After a long period of preparation (1999e), the Flemish parliament approved the GIS Flanders decree in 2000, which gave the Support Centre legitimacy (1999c; 2000c). With this decree, the preparations for the GRB also gained more solid footing, and design choices were made, pilot projects implemented and funding sought (2001d; 2002f).

In April 2004, the GRB decree was signed (2005; 2006c), setting out all the organisational preconditions and commitments needed to create and maintain the GRB, such as scope, standards, budgets and governance. Utility companies brought in around 50% of the funding, gaining considerable influence in return, as they were the only stakeholders in the GRB Board. The Flemish government funded the other half (2004; 2005; 2006d).

In 2006, the Support Centre was reorganised into an independent entity: the Agency for Geo-Information Flanders (AGIV) (2006d). AGIV scaled up production of the GRB (2009c), and, in 2013, the GRB was successfully completed according to plan. In late 2015, the GRB was declared open data (2016). At the start of 2016, AGIV merged with several other e-government services to form the new agency 'Informatie Vlaanderen' ('Information Flanders'). Efforts are currently under way to further integrate governance of SDIs, such as the GRB, into a new governance model encompassing all e-government information (interviews).

2.3.3. Comparing the Governance of the Two Cases

When we compare the governance evolution of the GRB and its predecessor with the BGT and its predecessor, we must first conclude that SDI governance is definitely not static. From the Royal Decree in 1975 up to the BGT of 2017, the governance structure changed some six times, often quite radically (Table 2.2). Although the GRB initiative is younger, SDI governance also changed considerably in this case (Table 2.2).

2.3.3.1. Interactions

Interestingly, both large-scale base maps seem to have emerged from collaborative network activities rather than top-down coordination. The GBKN had formal top-down status in 1975 but lost that in 1992. The GRB only became official in 2004, 14 years after the first collaborative large-scale mapping activities.

Another similarity between the GRB and BGT is that both experienced a period in which the whole undertaking was in jeopardy. For the BGT, this was around the start of the 1990s, when the Ministry demanded that the Cadastre cut its GBKN outlays and revoked the GBKN's legal status. At around this same period, the Minister intervened in Flanders, blocking further GI investments. Both

Table 2.2. Important governance transition moments in the Key Registry Large-Scale Topography (GBKN/BGT) case in the Netherlands and the Large-scale Reference Map (Cardib/GRB) case in Flanders, Belgium.

Year	Governance Changes BGT	Year	Governance Changes GRB
1975	Royal Decree GBKN	1990	Start of Cardib
1982	End of the Central Mapping Board	1992	GIS Flanders intervention by Minister
1992	Cadastre and national government pull-back, start of public-private partnerships	1999	End of Cardib, start of GRB
2008	Start of BGT programme	2004	GRB official decree
2012	New governance for transition to BGT	2007	Start of AGIV ¹
2017	New governance structure for greater cohesion between spatial key registries	2015	Integration of GRB in e-government services, establishment of Information Flanders

¹ AGIV= Agency for Geo-Information Flanders.

interventions seemed to act as a wake-up call for the interested parties, telling them that they needed each other to move forward.

The governance response to these interventions was opposite in the two different regions. In Flanders, the project evolved from governance with network and market type mechanisms to governance with more hierarchy and network type mechanisms. In the Netherlands, it moved from network and hierarchy type mechanisms to network and market type mechanisms in the 1990s. The later transition to the BGT, however, again brought hierarchy and network type mechanisms.

When the base maps became 'official authentic registries' and were incorporated into a larger digital national roadmap, the presence of hierarchical steering instruments increased. Figure 2.3 illustrates the rise and decline of hierarchical instruments in the cases. The graph was built as follows: for every hierarchical instrument found in the cases, a weight equal to 1 was added. The following hierarchical instruments were found: a law or decree, a central coordinating board, a central government with ultimate responsibility, a central government actively involved in decision-making, 50% or more of the SDI being centrally financed and mandatory standards. Although the graph should be interpreted schematically—as we would not suggest that our 'counting' of hierarchical instruments is complete—it nonetheless shows that over time hierarchical instruments became more prevalent in these SDIs.

Both large-scale base maps currently share a similar kind of interaction governance, with hierarchical steering such as a legal framework and a coordinating body in place, as well as network steering with the formation of several working groups and steering committees made up of all kinds of stakeholders. In addition, market type mechanisms are in place. The market is involved as a generator of the data and as a software provider, in most cases via tender procedures. However, hierarchical and network steering dominate in both SDI cases.

2.3.3.2. Actors

Another remarkable finding is the constant repositioning of stakeholders. This is most obvious in the division of the budgets. For production of the GBKN, in 1975, the Cadastre provided 50% (partly covered by a ministerial budget) and municipalities and public utilities together contributed 50%. After 1992,

Figure 2.3. Presence of hierarchical instruments in the SDI cases: 1971–2017 BGT (Netherlands) and 1990–2017 GRB (Flanders). Labels are in reference to key moments in the development of the specific large-scale base map.

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this changed. The Cadastre provided only 20%, municipalities provided 20% and public utilities contributed 60%. After a reshuffle in 2003, the new division became 20% for the Cadastre, 30% for the municipalities and 50% for the public utilities, though a consultancy company calculated a fair division as 24% Cadastre, 41% municipalities and 35% public utilities (2012d). With the BGT, the division between partners is less easily determined. The municipalities are responsible for the production process, and they get compensation from the central government, which also financed the necessary spatial data infrastructure. Together, they largely pay the bill for the BGT.

In Flanders, the Cardib initiative came mainly from public and private utility companies, sometimes with participation of interested municipalities. Before 1992, GIS Flanders was only for the central government, but the initiative was later opened to all government layers. When the GRB came about, the government needed input from the utility companies. They were mandated by law to pay some 50% of the budget. The Flemish government paid the other 50%. Municipalities do not have to bring any money, but, in order to diminish the costs of the updating process, they are legally required to deliver feedback and as-built information from newly constructed areas.

In both large-scale mapping processes, we found a growing importance of municipalities in creating and updating large-scale maps. Furthermore, the SDI stakeholders in both cases clearly learned from their past experiences. This was mentioned in the articles too, as the past was sometimes used to highlight how things had improved. Furthermore, the two cases learned from each other. Recall that Figure 2.1b showed articles about the GRB appearing in magazines covering only the Netherlands. Texts such as *'Let's finish the GRB quicker than the GBKN'* and *'The Belgians do it better'* enjoined SDI stakeholders to improve.

2.4. Discussion

2.4.1. Self-Organisation

The notion from Coetzee and Wolff-Piggott (2015) that SDIs are not yet self-organising and are mainly top-down structured seems not to apply to these two cases. Stakeholders in both cases reorganised their governance from time to time, especially when challenges arose and frustration with the product or process reached a boiling point. However, Coetzee and Wolff-Piggott (2015) also observe that *'the Dutch SDI development model is voluntary and its*

success lies in the strong self-organizing ability of the geospatial information community' (Coetzee and Wolff-Piggott 2015, p.124). Kok and Van Loenen (2005) similarly stress the importance of self-organising abilities, characterising the Dutch community as 'active'. Adaptive governance capacity is probably much weaker if self-organising abilities are less prevalent within the geospatial community (Grus, Crompvoets, and Bregt 2010).

Culture could be an important factor in these self-organising abilities. However, it should be noted that, despite the Netherlands and Flanders sharing the same language, their cultures are rather different. The culture of Flanders can be seen as its own cultural cluster, seemingly most closely related to Sweden, though they do not share much history (Minkov and Hofstede 2014). Further research on adaptive SDI governance in different countries and cultures could point out whether the reorganisation of SDI governance is culturally dependent, and if such a self-organising evolutionary trajectory is unique or a worldwide phenomenon.

The high cost of making a large-scale map is another possible reason why self-organisation emerged in these two cases, perhaps rendering network cooperation inevitable. Collaboration between public utility companies and local and central governments was necessary to make a large-scale map financially feasible. Other governmental spatial datasets, such as small-scale topography and land administration, are organised in a much more top-down fashion, both in Belgium and in the Netherlands.

Interesting in this respect is the relative absence of private parties in these initiatives, with the exception of privatised utility companies. The GRB did have a market-oriented start with the Cardib project, but that project failed to serve the interests of all stakeholders. The struggle for market collaboration in public-private partnerships is not unique to these SDIs. It has been documented in other financially costly initiatives, such as the European space programme Galileo (Mörth 2009); (Oikonomou 2016). More research on the market-government SDI relation may be helpful for improving collaboration or shedding light on potential problems. Furthermore, the influence of non-governmentally owned SDIs and their 'governance' could be an interesting research angle, as these bring (public) SDIs closer to end users.

Of course, the long history of GI collaboration in these regions could have

2 fostered self-organisation. Note that it took from 1974 until 2001 to complete the GBKN. It took 23 years, from the first Cardib ideas in 1990 until 2013, to complete the GRB. In addition, it took 25 years to advance from the first ideas for an object-oriented GBKN, in 1992, to the slated completion of the object-oriented BGT, in 2017. In all cases, the last ten years were the most productive. These productive years were sparked by a shared realisation that the current path would ultimately lead to SDI failure.

This does not seem unusual for spatial data infrastructures. Koerten (2011) studied, next to the GBKN, the development of the Dutch National SDI. At the time of his research, that project had suffered repeated failure, attributed to an overemphasis on technology and innovation. Upon the launch of yet another attempt, Koerten mused sceptically that *'the Dutch geoinformation sector is still not inclined to look back and learn from the past'* (Koerten 2011, pp.175–176). Today, however, the Dutch National SDI is thriving, and its usage has grown almost exponentially in the years since 2014 (PDOK, 2021). Again, this success came 20 years after the first proposals for the project and repeated false starts. As SDIs do not come in dozens there is no 'survival of the fittest', but (impending) failure does seem to have a simulative effect. Alas, this trajectory costs time and money.

According to Jessop (2003), *'given the growing structural complexity and opacity of the social world, failure is the most likely outcome of most attempts to govern it in terms of multiple objectives over extended spatial and temporal horizons—whatever coordination mechanism is adopted'* (Jessop 2003, p.106). This suggests the need for further research on the possible fly-wheel effect of the threat of imminent SDI failure.

2.4.2. Mix of Governance Interactions

This study's findings show remarkable resemblance to the conclusion of Lance et al. (2009) in their study of two SDI cases in Canada and the USA. They found a growing importance of central coordination and a movement away from autonomous SDI stakeholders in favour of formal top-down recognition. Their conclusion is as follows:

'The use of hierarchical controls... runs contrary to the public management discourse on network governance, which purports that informal, horizontal networks are replacing formal, vertical/hierarchical organization. However,

a shadow of hierarchy may actually facilitate the 'joining up' of government geospatial information systems' (Lance, Georgiadou, and Bregt 2009, p. 265).

The fact that SDIs nowadays have more hierarchal controls, both in North America and in the Netherlands and Belgium, does not automatically mean that SDIs are now governed in an overtly authoritarian manner. Vancauwenberghe (2013), in fact, notes an attempt to introduce more network coordination within the Flemish SDI. The histories of the two large-scale base maps studied here suggest that harmonious collaboration is more important to move ahead than autonomy. Other coordination mechanisms such as markets and networks are also still present. Academics (e.g. Dietz, Ostrom, and Stern 2003; Edelenbos et al. 2015; Rijke et al. 2012) increasingly agree that such a mixture of governance forms is important for achievements or results: *'Continuously steering towards interaction, participation and consultation tends to produce inertia; over-emphasis on hierarchical top-down control has the disadvantage of driving parties to dig in their heels, leading to resistance, delays and postponements of implementation'* (Edelenbos et al. 2015, p.185).

Not coincidentally, a mixture of governance forms is one of the three prescriptions of what is called 'adaptive governance' (Dietz, Ostrom, and Stern 2003). The other two are analytic deliberation and nesting. Analytic deliberation concerns formation of well-structured dialogue by including different kinds of actors with different interests and perspectives. By keeping them informed and around one table, trust is said to flow more easily and consensus is produced for dealing with conflicts. Nesting refers to the layering of institutional arrangements. This makes arrangements complex and redundant, but this is necessary, as simple governing strategies like 'command and control' often fail in complex systems (Dietz, Ostrom, and Stern 2003).

Can the SDI cases in this research be considered perfect examples of adaptive governance? Probably not, as radical governance changes were sometimes needed to improve. However, both cases evolved towards use of a broader interaction mix, with more stakeholders involved and also the broadest set of laws, policies and standards applied. Therefore, it could be that, with the help of self-organisation, SDI governance automatically advances towards a more adaptive form. Further research is needed to confirm this.

2.5. Conclusions

Based on the key governance transitions found in the two cases, we can conclude that SDI governance is adaptive, as it changed considerably during the evolution of the two registries. However, we can also conclude that most governance models did not hold up very long, as they either were not meeting their goals, were not satisfying all actors or were not in alignment with new visions and ideas. Nothing, not even legal requirements, could withstand the need for a change in SDI governance.

The general notion that network governance is a contemporary phenomenon is contradicted by the origins of both our SDI cases, as both emerged from network collaboration. Their governance evolution thereafter differed. GBKN/BGT governance transformed from an hierarchy-network organisation towards a mainly market-network driven governance in the 1990s under the influence of New Public Management and poor financial and production performance. The GRB accumulated more and more hierarchical influences over the years as it gained legitimacy. This also later happened to the BGT when it gained the status of 'key registry'. This supports the finding of Lance et al. (2009) that hierarchical controls are increasing within SDIs.

This does not mean that SDIs are now governed in a purely top-down fashion, as other governance forms, such as networks and markets, are still present and important. It merely shows that central governments are taking SDIs more seriously and expanding their steering possibilities to govern SDIs more effectively, which also improves its adaptive capacity. However, self-organising abilities of SDI actors also seem an important precondition for successful adaptive SDI governance. By applying both in SDI governance, SDI's survival seems to be ensured for the future.

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Chapter 3

Understanding Governance Dynamics: The Governing System of Spatial Data Infrastructures

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Abstract

The importance and influence of spatial data has risen in all kinds of governmental and non-governmental processes, giving spatial data infrastructures (SDIs) a key role in spatial data sharing and dissemination. SDIs are nowadays challenged by new technologies and user demands. Proper SDI governance seems essential, but it is unclear to what extent current SDI governing systems are fully equipped to deal with the dynamics and complexity of SDIs. This research proposes a governing system framework for analysing the governing system of SDIs, adapted from the concepts of Kooiman. This framework is applied to two Dutch SDI cases: the Risk Map and the New Map of the Netherlands. With the help of the framework, the strong and weak aspects of the governing system of SDIs become more apparent and insights emerge on which interactions, images, instruments, actions and structures enable or constrain SDI governance. By observing changes in governing systems over time, SDI governance dynamics become visible. The governing system framework brings a new perspective to SDIs and SDI theory and is a potentially useful analytical tool for SDI governors.

Keywords: Spatial data infrastructure (SDI); governance; governing system.

3.1. Introduction

In recent years, governments, companies and NGOs have improved their spatial data management by introducing a spatial data infrastructure (SDI). Spatial data, also called geo-information, has become a 'critical component' providing understanding about what happens where. Integration of spatial data with governmental services is favourable to '*economic growth, national security, sustainable social development, environmental sustainability and national prosperity*' (UN-GGIM 2018, p.4). In many instances, an SDI is implemented to facilitate efficient spatial data sharing between organisations by diminishing data duplication and fragmentation of spatial information.

Previously, '*The principal objective of developing an SDI is to provide an appropriate environment in which all stakeholders, both users and producers, of spatial information can cooperate with each other in a cost-efficient and cost-effective way to better achieve their targets*' (Rajabifard, Feeney, and Williamson 2002, p.13). Later on, this objective shifted from cost reduction to maximising benefits, by focusing more on the users and their needs (Rajabifard et al. 2003). With the rise of the internet and influence of the 'open government' paradigm, many governmental SDIs opened up and are not only focused on increasing benefits for their own organisation, but also for society as a whole.

Open spatial data has resulted in growth in the use of spatial data (Hansen, Hvingel, and Schröder 2013), but it also put pressure on data business models (Welle Donker 2009) and resulted in a continuously growing group of SDI stakeholders (Vancauwenberghe and van Loenen 2017) with various needs and interests (Coetzee et al. 2018). SDIs are constantly challenged by new technologies and user demands. This is partly due to the complex, multi-stakeholders, multi-level, technical and open nature of SDIs. SDIs should therefore not be seen as stationary, but as complex adaptive systems that adapt and evolve over time (Grus, Cromptvoets, and Bregt 2010; Sjoukema, Bregt, and Cromptvoets 2017). A proper SDI governing system which enables SDI governance processes and steers SDI development in the desired direction appears essential, but it is unclear to what extent current SDI governing systems are fully equipped to deal with the dynamics and complexity of SDIs.

In this paper, we will propose a framework for analysing the governing system of SDIs and its dynamics, so that we can understand the key processes that

enable or constrain SDI governance. By applying the framework to two SDI cases, we can also evaluate the strong and weak points of this framework. First, we will conceptualise what we mean by 'governance' and the 'governing system' in this paper.

3.2. Governance and the Governing System

3.2.1. Governance

The word 'governance' has many definitions and meanings. To distinguish the multiple governance concepts from each other, many adjectives are added, such as 'good' governance, 'network' governance (Rhodes 1996), 'corporate' governance (Kersbergen and Waarden 2004), 'collaborative' governance (Ansell and Gash 2008), 'adaptive' governance (Dietz, Ostrom, and Stern 2003), 'fit-for-purpose' governance (Rijke et al. 2012) or 'interactive' governance (Kooiman 2003). Theories on governance are still an ever-expanding universe, which does not make it an easy subject to grasp.

Because of this wide range of governance definitions and ideas, we would like to explain the governance perspective we use in this research. This is not to state that we have *the* governance definition, but to understand the governance lens we use to study SDIs in this research. Our perspective is a holistic one, in which we refer to governance as the governing process in which multiple actors (both public and private) can influence this process through interactions. Interactions are a key element in governance: *'interactions shape actors and actors shape interactions'* (Kooiman 2003, p.8).

Structures or institutions will enable or constrain the governing process, ensuring that 'things don't fall apart' (Giddens 1984; Kooiman 2003). Structures can be formal rules (such as laws, organisations, contracts, standards), but also informal (such as culture, norms and values). Structures have a dual nature: they shape action and are stable in the short term, beyond the control of one actor. However, in the long term structures are changeable and shaped by the actions of the interacting actors (Giddens 1984; Sewell 1992; Kooiman 2003).

Because structures influence governance interactions, a distinction is made between an 'actor' or 'intentional' level, where the day-by-day interaction between actors is happening, and a 'structural' or 'institutional' level, where rules and resources enable and constrain the actor level (Figure 3.1) (Kooiman

Figure 3.1. Relation between the actor level of governance, where actors interact and the structural level, which enables and constrains the actor level. Adapted from (Kooiman 2003).

2003).

‘Governance’ theories originated from insights about networks (Rhodes 1996; Klijn 2008), but we are also aware that these theories about governance networks did not replace older governing theories such as Weberian bureaucracies or the market-driven ideas from New Public Management, but added an extra layer (Pollitt and Bouckaert 2011). Therefore, we try not to set boundaries around governance; rather, we see that top-down or hierarchical interactions, horizontal, network or collaborative interactions and bottom-up or self-organising interactions all play an important role in the entire governance process.

3.2.2. Governance and SDI dynamics

Several scholars who tried to summarise and find parallels between the multiple governance forms (e.g. Rhodes 1996; Kersbergen and Waarden 2004; Pollitt and Bouckaert 2011) conclude that governance is shifting. Since the 90s, more and more authors have described the rise of network-oriented approaches to governance in contrast to hierarchal and market-driven forms. These networks are largely self-organising (Rhodes 1996), posing challenges for ‘classical governing’: *‘Traditional institutions of checks and balances on power and accountability could become obsolete, or at the very least less effective’* (Kersbergen and Waarden 2004, p.155). Rhodes notes that *‘Governance as self-organizing networks is a challenge to governability because the networks become autonomous and resist central guidance’* (Rhodes 1996, p.667).

Interestingly, a different development, moving from self-organising networks towards more central guidance, has been witnessed in the SDI domain in several countries: the Netherlands, Belgium (Sjoukema, Bregt, and Cromptvoets 2017),

the United States (Lance, Georgiadou, and Bregt 2009) and Australia (Masser, Rajabifard, and Williamson 2008). SDIs which originated from network initiatives in the early 90s (Masser 1999) began to strive later on for more hierarchical influences, such as central coordination, laws and policies in order to gain legitimacy (Sjoukema, Bregt, and Crompvoets 2017; Lance, Georgiadou, and Bregt 2009). The reason could be that SDIs are relatively young infrastructures whose institutions are not yet fully developed (De Man 2006). This maturing of SDI governance makes it an interesting subject to analyse how governing systems change.

3 As we see SDIs as complex adaptive systems (CAS) (Grus, Crompvoets, and Bregt 2010), it is questionable if there is an optimal generic governing system for SDIs. Or alternatively, it *'is the question of whether it is at all possible to govern the messy and unpredictable nature of CAS'* (Duit and Galaz 2008, p.329). As every SDI will have a specific governing system and context due to its complexity, path-dependency and openness, every SDI may also need an individual governing system. However, we can evaluate governing systems over time, compare the differences and analyse what works well and what does not.

A key feature of CAS is their unpredictability and non-linearity. These features are also present in governance (Kooiman 2003; Duit and Galaz 2008; Rijke et al. 2012; Kooiman and Bavinck 2013). Periods of incremental change can be followed by fast and sudden change with major and irreversible consequences, due to threshold and cascading effects (Duit and Galaz 2008). Teisman (Teisman 2000) and Klijn & Koppenjan (2016) call these tipping points in governing processes 'crucial decisions'. A crucial decision is identifiable when the composition of actors, the course of interactions and the content of the governance process dramatically change (Klijn and Koppenjan 2016).

3.2.3. The Governing System

In this research, we use the conceptualisations of the governing system by Kooiman (2003). We use his theoretical concepts, as Kooiman is one of the few governance scholars who uses a system perspective on governance. Many scholars only focus on partial aspects of governance, but Kooiman's perspective, which has been categorised as the socio-cybernetic approach (Rhodes 1996), helps to provide an overview of governance, its relations and interactions. As this approach also acknowledges the influence of complexity, diversity and

dynamics on governance, these theories are a good fit for studying governance of complex adaptive systems such as SDIs (Kooiman and Bavinck 2013). Kooiman's theories even explain changes in governance paradigms themselves (meta-governance) (Kooiman 2003). As we explained earlier, governance paradigms such as New Public Management and Open Government have had an impact on the goals and development of SDIs (Sjoukema, Bregt, and Crompvoets 2017).

However, we are also aware that this highly dynamic system perspective has a downside, as it is either too abstract or too difficult, and too all-encompassing for operationalisation on a more detailed level. Nevertheless, as we witness SDI governors in practice struggling to gain an overview of governance processes, we think it is an insightful analytical framework to use on SDIs. Furthermore, to scope our research we focus mainly on the conceptualisations of the governing system and adapt and apply it to SDIs to make our system less abstract.

Kooiman's governing system can be broken down into four elements: images, instruments, action and structures (Figure 3.2) (Kooiman 2003). All governing action starts with a perceived problem, an image. Problems are not objective: *'They are social constructions; perception of actors on what makes a situation problematic'* (Klijn and Koppenjan 2016, p.45). Because every actor is autonomous yet interdependent, these 'perceptions' or 'images' can be dissimilar, leading to disagreements and conflict (Klijn and Koppenjan 2016).

Governing instruments are used to force, enable, detect or facilitate certain interactions. Choosing an instrument is close to image formation, while putting an instrument to use is close to governing action. In governance, all actors can

Figure 3.2. Simplified conceptual framework of the governing system, based on conceptualisations from Kooiman (2003).

apply instruments, but not all actors can apply all instruments: this depends on their governing position and resources. ‘Soft instruments’, such as information and advice, can be applied by more actors than ‘hard instruments’ such as taxes and regulations (Kooiman 2003).

Once images are formed and instruments are chosen, they will be applied for governing action. This does not necessarily mean that the action will be properly adopted. The action element *‘relies upon convincing and socially penetrating images and sufficient social-political will or support’* (Kooiman 2003, p.62). Via feedback from affected actors, it can be determined whether the governing action was effective and appropriate. The initial image will be altered by this feedback (Kooiman 2003).

The structural level is where structures such as institutions and resources reside. Structures are necessary to steer, guide and facilitate governing action, but they can also frustrate and block governance. Governance focussed on changing the structural level is what Kooiman calls ‘second-order governance’, as opposed to ‘first-order governance’ which can be seen as the day-by-day governance aimed at problem solving (Kooiman 2003).

3.3. Research Method

3.3.1. Cases

To understand the governance dynamics of SDIs, we use the conceptual framework of the governing system to study two Dutch SDI cases: the ‘Risk Map’ (*Risicokaart*) and the ‘New Map of the Netherlands’ (*Nieuwe Kaart van Nederland*). One of the reasons for choosing these cases is their age, as both cases date from around 2000, which makes it possible to review the changes in their governing systems over time. Both cases can be seen as goal-oriented SDIs, as they focus on a certain theme to collect and disseminate spatial data. Both cases operate in a multi-actor environment where local, regional and national governments are involved. Most data of these SDIs are also openly accessible from quite an early stage. However, their governing systems and their developmental paths are very different. By choosing two distinct cases, it can be determined whether it is useful to perform an analysis with the governing system framework.

To order data on governance processes over time, we use the heuristic method

from Klijn and Koppenjan (Klijn and Koppenjan 2016) to divide the cases into 'rounds'. A 'round' is a time interval which starts and ends with a crucial decision. A crucial decision is identifiable when the composition of actors, the course of interactions and the content of the governance process dramatically change (Klijn and Koppenjan 2016). In each case, we identified a crucial decision that forced the governing system to change. The following section will describe the cases and the identified rounds.

3.3.1.1. Risk Map (*Risicokaart*)

In 2000, a great disaster struck the city of Enschede, the Netherlands. A fireworks depot exploded in close proximity to a residential neighbourhood. Twenty-two people were killed, 950 persons were injured, around 500 homes were destroyed and 1,500 buildings were damaged. One of the conclusions was that many citizens were not aware that they were living near a fireworks depot and that information about such hazardous locations was fragmented (Commissie Oosting 2001). Realising that there were many more potentially dangerous companies and facilities in the Netherlands, the Dutch national government ordered the creation of a so-called 'Risk Map' (Dutch: *Risicokaart*) which should be accessible for all citizens and on which all potential hazards should be visible (De Vries 2001).

To create the map, the national, regional and local governments with the responsibility to grant permits for these hazardous facilities, supplied information for the Risk Map. This information is collected in a central database and disseminated. Apart from serving to inform citizens, the Risk Map was also of value for emergency services which prepare for and prevent potential disasters, and for organisations planning new housing areas. The Risk Map is open to everyone, although more detailed information is only accessible for governments via a log-in.

Two rounds for the Risk Map can be distinguished: one round is the period from 2000 till 2013 and the other is from 2014 till now. After multiple negative signals in 2013, such as a negative inspection report and a letter of protest from civil servants, the crucial decision came that the Risk Map could not continue in its current form. On a technical level, the SDI had become impossible to maintain, because it used legacy software and many customised add-ons. On the institutional level, roles and responsibilities of actors were not clear enough to coordinate the Risk Map properly. Or in other words: the governing system

no longer functioned well enough. Since then, considerable effort has gone into renewing the governing system and improving the Risk Map's data and technology.

3.3.1.2. New Map of the Netherlands (*Nieuwe Kaart van Nederland*)

As a small and densely populated country, the Netherlands has a long tradition of spatial planning. However, to satisfactorily plan how many new houses and commercial buildings are required and where they should be located, one needs information on and an overview of all the current plans. Therefore, the 'New Map of the Netherlands' (*Nieuwe Kaart van Nederland*) was presented in 1997, based on a project from several planning associations to collect all local and regional plans and assemble them into one national map.

The first 'New Map' was mainly an analogue, one-time affair, yet people were aware that this was valuable information which should be updated. An organisation devoted to the New Map of the Netherlands was established, which collected all plans from local municipalities, digitised and standardised them and disseminated them to the public as the New Map of the Netherlands. As an important policy instrument for analysing and monitoring spatial planning, it received budgetary support from the Ministry of Housing, Spatial Planning and the Environment (VROM). This all continued until 2010, when funding from the ministry suddenly stopped, despite the popularity of this information source.

In view of its popularity and the valuable data it provided for spatial planners, researchers and governments, several initiatives were undertaken to research a rebirth of the New Map. In 2018, a few individuals involved in collecting and disseminating data about spatial planning formed an organisation, established a foundation and succeeded in relaunching the 'New Map of the Netherlands'.

As with the Risk Map, two rounds can be identified within the New Map of the Netherlands case. The crucial decision of the Ministry of Housing, Spatial Planning and the Environment (VROM) to stop funding this map in 2010 marks the end of round 1. Without these resources, the New Map was not able to continue. However, this did not end the need and ideas for a New Map, and by self-organisation, the New Map underwent its rebirth. This phase of self-organisation from 2010 onwards forms the second round.

3.3.2. Data collection

For our empirical analysis, we used two kinds of sources. On the one hand, we conducted semi-structured interviews with involved actors. Actors were asked how they perceived the SDI and its governing system in the past (when they became involved in the SDI), how the SDI and its governance developed from then and how they experienced it nowadays. In this way, a great deal of information about the governing system and its evolution unfolded. In total, we spoke to nine persons about the New Map of the Netherlands and to eight about the Risk Map. The interviewed persons held a variety of SDI positions, such as SDI coordinators, data users and data providers, and had varying track records (long and short involvement). This provided a complete picture of the governing system and its inner workings.

However, as we wanted to study the longitudinal development and memories can change, we also used documents as a complementary information source. An important advantage of documents is that they are stable and therefore not altered by memories. For our document analysis, we used primary sources such as official policy documents, newsletters and reports as well as articles in industry magazines. Furthermore, every interviewee was asked whether she or he had important document sources to study. In total, 33 additional documents were analysed for the Risk Map and 26 for the New Map of the Netherlands.

3.3.3. Coding

Both sources of information, the documents and transcripts of the interviews, were coded with the help of ATLAS.ti coding software. For this coding, the qualitative content analysis method, also known as ethnographic content analysis, was used. With this method, a coding framework is iteratively built up by going through the contents (Bryman 2012). In this case, we started with four main categories (image, instrument, action and structures) and combined the categories with information about what kind of image, instrument, action or structure we found in a piece of text.

To begin with, the above method was used to code the documents and interview transcripts of the Risk Map, resulting in a long list of codes about images, instruments, action and structures. During coding it became apparent that, to obtain a better understanding of SDI governance dynamics, we would need two extra categories: interactions and SDI performance qualities. As

governance is founded on interactions, we added the interaction category to understand the formality and direction of interactions used within a round. The category of SDI performance qualities was added to get a basic understanding of the performance, data quality and use of the SDI. SDI governance shapes SDI qualities, but SDI qualities also shape SDI governance. It is essential to understand this relationship in order to explain SDI governance dynamics.

In the next step, multiple codes were combined or refined, so that analysis of the codes is more efficient and it becomes easier to find patterns. The creation of these subcategories was also based on findings from current scientific SDI and governance literature. For many subcategories, it was decided to make an additional distinction as to whether the subcategory influenced the governance positively or negatively. Every piece of coded text was revised with the new refined coding framework. This framework was also used to code the other Risk Map and New Map of the Netherlands texts. Finally, all codes were checked for consistency and redundancy. Every interview and document was checked at least twice.

The next section will operationalise and explain the coding framework we used.

3.3.4. Coding framework

In the final version of the coding framework, 60 codes were used. As most codes had both a positive and negative attribution, 30 code subcategories divided over six main categories (images, interactions, instruments, actions, structures and SDI performance qualities) were used. This section will briefly explain these codes and their link with scientific literature.

3.3.4.1. Images

The following codes were used to code the category of images.

- Satisfaction (positive/negative)
- Feedback loop (positive/negative)
- Collaborative (aligned/unaligned)
- Goal/vision (explicit/individual)

Every involved actor has their own perception about the SDI and the governing system. Collecting these images is useful for understanding the satisfaction of actors. In this research we coded both positive and negative remarks to gain

an indication of the *satisfaction* of actors regarding the SDI and its governing system.

Feedback loops, both positive and negative, are an important feature of complex adaptive systems when adjusting inputs and processes (Grus, Crompvoets, and Bregt 2010) and are also essential for SDIs (De Man 2006). With continuous feedback, the governing image can be adjusted (Kooiman 2003). Therefore, we coded both *positive feedback* and *negative feedback* to get a sense of the feedback flow.

As images can be very dissimilar, actors should make their image explicit in order to make the image controllable and the governing action legitimate (Kooiman 2003). To converge images, actors need time, space and processes for discussion to reconcile their images with other actors (Dang, Visseren-Hamakers, and Arts 2015). Converging the images of involved actors is an important step in making the governing action more effective. We coded the collaborative images between actors as *aligned* or *unaligned* by identifying agreement and disagreement among involved actors.

An explicit image is a vision or common goal. When a vision is shared by all actors, it is a powerful tool (Kok and van Loenen 2005). In this sense the vision will be shaped by the collective images of individual stakeholders and vice versa: images of individual stakeholders will mirror the shared and outspoken vision. We coded goals or visions as being *explicit* or *individual*. The latter code is mainly suitable for qualitative analysis aiming to understand how actors see the future of the SDI.

3.3.4.2. Interactions

The following codes were used to code the category of interactions.

- Interferences (bottom-up/top-down)
- Interplays (bottom-up/top-down)
- Interventions (bottom-up/top-down)

Governance processes consist of interactions between actors, bound by structures. However, the choice for certain types of interactions explains whether an SDI is mainly hierarchically governed, network-governed or self-governed. Kooiman (2003) distinguishes three types of interaction: interferences, interplays and intervention. *Interferences* are the least organised kind of societal

interaction and can be seen as the 'primary' daily societal interaction processes. *Interplays* can be seen as 'horizontal', semi-formalised interactions. Interplays are the central interaction form of network governing. *Interventions* are the most formalised interactions and are aimed at direct influence (Kooiman 2003).

To make a further distinction in interaction, the direction of interaction was assessed. Therefore, we made a distinction between *bottom-up* and *top-down*, determined by the hierarchical position of the actor and the direction of the interaction. Top-down does not mean in this context that the interaction necessarily came from the actor at the top of the hierarchy (such as the national government), but that the interaction came from an actor in a higher governing position.

Although interplays are meant as horizontal interactions, they can have a kind of direction. For example, in a working group where actors from both the national and the local governments participate, interplays can have an implicit direction. However, it is not always possible to distinguish this.

3.3.4.3 Instruments

The following codes were used to code the category of instruments.

- Information (detector/effector)
- Organisation (detector/effector)
- Rule (detector/effector)

There is an enormous array of potential governing instruments (Kooiman 2003). Multiple scholars have categorised governing instruments (e.g. Bemelmans-Videc, Rist, and Vedung 1998) and lists of useful SDI governance instruments also exist (see Cromptvoets et al. 2018; Vancauwenberghe and van Loenen 2017). However, in this research we are more interested in the balance and choice for certain instrument types than in exactly what an instrument aims for.

Kooiman (2003) describes three categories of instruments, which are connected to his categorisation of interaction types: *information*, *organisation* and *rule*. Under the category of information, we coded communication instruments, such as newsletters and presentations, as well as more informal and thus interferential type of interactions, such as phone calls and informal discussions for sending or obtaining information. Under organisation, we coded more formalised instruments such as task allocation and the formation of work and

steering committees. Under rule, we coded the most formal instruments, such as policies and laws.

An extension was made to draw a distinction between ‘detectors’ and ‘effectors’ as proposed by Hood (1983). The previously stated coding examples for instruments can be seen as effectors: instruments which are used to influence society (Hood 1983). Detectors are instruments which are used for taking in information and thus strengthen the image. An example of a detector for information is collecting feedback on a conference floor. An example of a detector instrument of organisation is using research, reporting or key performance indicators to gain information in a more structured way. An example of a detector for rule is an official investigation, audit or inspection.

3.3.4.4. Action

The following codes were used to code the category of action.

- Leadership (present/lacking)
- Coordination (present/lacking)
- Self-organisation (present/lacking)
- Collaboration (present/lacking)

To steer governing action in the right direction, leadership, coordination and self-organisation can be used (Kooiman 2003). Additionally, in SDI literature, leadership and the need for ‘white knights’ is designated as ‘critical’ for an SDI (Kok and van Loenen 2005; Craig 2005). Besides leadership, SDI literature recognises the need for coordination as essential (Dessers et al. 2012; Vancauwenberghe 2013). Therefore we coded *leadership* and *coordination*. For each code in the action category we coded them as *present* or *lacking*.

Self-organisation is also an interesting example of a governing action for SDIs (Kok and van Loenen 2005; Welle Donker and van Loenen 2017). The self-organising ability of the SDI community seems an important precondition for ensuring SDI survival (Sjoukema, Bregt, and Cromptvoets 2017). In addition, we coded self-organisation as being available or lacking, although the latter is not often mentioned.

We added an extra action element not found in Kooiman, *collaboration*, as close collaboration will foster governing action. It can be argued that collaboration is almost the same as self-organisation. However, during coding we observed that

weak collaboration or coordination can lead to more self-organisation, as actors start to create various solutions individually, which leads to more information fragmentation. Like the other action categories, we coded for collaboration as being either *present* or *lacking*.

3.3.4.5. Structures

The following codes were used to code the category of structures.

- Roles and responsibilities (enabling/constraining)
- Ownership (enabling/constraining)
- Law (enabling/constraining)
- Budget resources (enabling/constraining)
- Time resources (enabling/constraining)
- Knowledge resources (enabling/constraining)
- Political capital (enabling/constraining)
- Social capital (enabling/constraining)
- Standards (enabling/constraining)
- Technology (enabling/constraining)
- Support (enabling/constraining)
- Trust (enabling/constraining)
- Culture (enabling/constraining)

As all governing actions are bound by structures, structures play a vital role in the governing system. However, they can both enable or constrain governing action. Therefore, for each code in the structure category we identified whether it is *enabling* or *constraining*.

The involvement of stakeholders can be institutionalised by creating coordinating functions or entities. In this way, roles and responsibilities are allocated and some hierarchical difference between the coordinator and the coordinated organisations is generally implied (Crompvoets et al. 2018). A special kind of responsibility is ownership, which adds an extra dimension of commitment for stakeholders to (a part of) the SDI system (Ansell and Gash 2008). Therefore, we coded both *roles and responsibilities* and *ownership*.

Legal frameworks, formal policies and regulations for data sharing are often mentioned as important enablers for SDIs (Rajabifard, Feeney, and Williamson 2002; Vancauwenberghe et al. 2018; UN-GGIM 2017; Vancauwenberghe and

van Loenen 2017). Yet, laws can also become a constraining factor. In cases where these policies and laws were legally binding, we categorised these formal structures into the category *law*.

The choice for instruments is strongly connected with the availability of resources on the structural level. Indeed, the availability of *budgetary resources* is an important condition for SDIs (Welle Donker 2009; Vancauwenberghe and van Loenen 2017; Welle Donker and van Loenen 2017). However, in our coding framework we also recognised four other resources: *time resources*, *knowledge resources*, *political capital* and *social capital*. Among *time resources*, we assume that actors have permission and opportunity to spend time on a certain subject. Among *knowledge resources*, we assume the availability of knowledge and expertise. Although Kooiman (2003) uses the term social-political capital, we choose to split this concept in two. In our research, *social capital* denotes availability of and access to social networks. By *political capital*, we mean availability of and access to hierarchical decision-making power. A person with political capital does not have to be a politician, but can also be the executive director of an organisation.

We used two codes which are especially applicable to SDIs. These are *technology* and *standards*. Technology (or access network) and standards are important enablers for SDIs and are seen as core SDI components (Rajabifard, Feeney, and Williamson 2002). However, we noticed during coding that these two structures can also act as constraints to SDI renewal.

Support can be seen as the structural component of governing action (Kooiman 2003). Support from both the political level and the 'work floor' is needed to enable SDI development (Kok and van Loenen 2005; Vancauwenberghe and van Loenen 2017; Vancauwenberghe et al. 2018). We did not make a distinction between these levels, as by combining the support code with, say, the political capital code, the source of support can become clear.

Finally we coded two other soft structures: *trust* and *culture*. Trust is an important pre-condition for governing actions such as collaboration. Culture proved the most difficult structure to code from texts, as it is usually an unconscious structure. An enabling or constraining culture is only recognised by actors when persons are introduced to a new organisational culture.

3.3.4.6. SDI performance qualities

As it appeared that developments in SDI governance cannot be disconnected from SDI performance, we added three codes to obtain a basic indication of SDI qualities:

- Use (use/non-use)
- Data provision (good/bad)
- Data quality and availability (high/low)

Although it is not our goal to properly assess an SDI, it is helpful to gain insights into the SDI performance qualities during the governance rounds. We coded six aspects of SDI performance in three pairs: *good data provision/bad data provision*; *high data quality and availability/low data quality and availability*; and *use/non-use*. Under data provision, we understand the willingness and the actual provision of data by actors. Data quality and availability is a combined code, encompassing data quality aspects as well as the availability of services. Of course, data is shared to be used: the codes for use and non-use indicate whether actors state that they deliberately use or do not use the data provided by the SDI.

Figure 3.3 summarises the coding framework used, as embedded in the framework of the governing system.

3.3.5. Analysis

Coding the documents and transcripts had two purposes. On the one hand, it provided more insights and better interpretation of the collected material for a qualitative analysis of how the SDI and its governing system evolved. On the other hand, it helped us to see patterns and trends emerge, and to discover differences in the governance system between rounds.

To discover patterns and trends in documents and transcripts, the frequency of a code can be used. However, as the total number of coded texts was not equal between rounds, we had to look at the relative frequency of codes. These were calculated via two methods: one was to calculate an indicator per code based on the total number of codes per round; the other indicator was to look at the relative frequency within a category of codes, for example by observing the relative presence of the code 'collaboration' within the category 'action'. If the difference between the first round and the second round was more than

Figure 3.3. Visual summary of the coding framework, positioned in the framework of the governing system.

0.5% for the first indicator and/or more than 1.5% for the second indicator, this difference was recorded as a shift. Appendix B shows the coding results.

It should be mentioned that, despite the careful process of coding, looking at these relative code frequencies is not a trustworthy method to make strong statements about a governing system in a certain period. This is because the codes' source material can cause them to become biased. For example, many documents and interview candidates explained the origin of the Risk Map with the fireworks disaster in Enschede and the concept of a Risk Map which emerged from it. This causes a very high code frequency for 'explicit vision' in round one of the Risk Map compared to round two, but this does not necessarily mean there is a lack of explicit vision in round two. Nevertheless, using these frequencies as an indicator in combination with the qualitative analysis proved a helpful tool for identifying trends and shifts in the governing system.

3.4. Results

3.4.1. Risk Map

3.4.1.1. Round 1: 2000 – 2013

After the fireworks disaster in 2000 in Enschede, the image was clear: there was a lack of central information about potential hazards and the communication about these potential hazards to citizens was poor (Commissie Oosting 2001). This image was not entirely new. A few provinces had already started to work on a risk registry before 2000. But after the disaster, the national government demanded that there should be a Risk Map at the national level (De Vries 2001).

Several roles and responsibilities were allocated by the national government. Municipalities were assigned the task of making an inventory of potential hazards and a crisis response plan for each hazard. The Ministry of the Interior and Kingdom Relations took the initiative to develop a model for a Risk Map in collaboration with municipalities and provinces. The Ministry of Housing, Spatial Planning and the Environment was given the task of setting up a registry for hazardous substances (De Vries 2001). At first, this registry was intended as an independent database, but after a successful lobby it was decided in 2005 to integrate this registry into the Risk Map and use it as one of its main datasets. However, ownership of this registry remained with the Ministry of Housing, while the Risk Map was owned by the Ministry of the Interior. Because both ministries had the task of designing laws and regulations (one of them for the Risk Map

and the other for the registry for hazardous substances), close collaboration between the provinces and ministries was necessary to prevent inconsistencies.

The provinces had the task of creating and maintaining a Risk Map. At that time, the development of an SDI was technologically challenging. This assignment thus ushered in a period of innovation and self-organisation. Several provinces took the initiative to develop a Risk Map system and experiment with its creation. As provinces were not used to collaborating with one another to develop a central system, the first idea was to create a model from which each of the 12 provinces could create its own Risk Map SDI. By mixing several best practices and designing a flexible system which provinces could extend, a central SDI was designed (FO MRK projectteam, PinkRoccade, and Geodan 2003). After several years of development, the first version of the Risk Map was launched in 2006.

After the terrorist attack on New York's World Trade Center in 2001, the scope and goal of the Risk Map suddenly became a point of political discussion. It was argued that a public map which located all potential risks could be easily misused by terrorists. The discussion was settled by creating a public version for citizens providing a basic overview and a secured environment where crisis response teams and governments could obtain more detailed information.

In 2007, the Risk Map and its accompanying laws were in place. The two ministries withdrew their active involvement and transferred most responsibilities for coordinating, maintaining and developing the Risk Map to the twelve provinces of the Netherlands. Because twelve provinces had to maintain one national application, they founded a provincial shared service organisation for maintaining the technological aspects of the Risk Map. Each province stayed responsible for policy making concerning the Risk Map. The data was mainly provided by municipalities.

The Risk Map was subjected to continued experimentation and innovation. New features were added and a pilot for a cross-border data infrastructure was organised. In 2010, many legal tasks and responsibilities of the provinces concerning safety and crisis management were transferred to newly created 'safety regions'. These regions became main users of the professional version of the Risk Map, while use by provinces diminished. Additionally, ownership of the Risk Map was transferred from the Ministry of the Interior to the Ministry of

Justice and Security. However, tasks and responsibilities for the Risk Map itself remained with the provinces.

After this shift in responsibilities, support for the Risk Map crumbled. The national government had been showing little interest since the implementation of the legal framework, and with the transfer of legal responsibilities to the safety regions, provincial support weakened as well. During the years of innovation and experimentation, features were added without revising the system itself, making it a very complex and costly system to maintain and improve. Furthermore, providing the data was very time-consuming for the municipalities and not every municipality had the knowledge to provide the data accurately, which resulted in poor data quality. Because of these problems and the lack of confidence in a solution, several provinces actively chose to diminish support and execute tasks only if they were legally necessary.

At the end of 2013, an inspection by the Ministry of Justice and Security concluded that the Risk Map was not an effective instrument for risk communication, because of the untrustworthy data quality and a lack of coordination. These problems were seen as interrelated (Inspectie Veiligheid en Justitie 2013). In 2014, the twelve provincial coordinators urged changes as the technologies and contents of the Risk Map, as well as policies for administering it, were all outdated.

3.4.1.2. Round 2: 2014 – Now

The provincial coordinators' call for change was heeded. A task force studied the problems associated with the Risk Map and made recommendations for improvements. A central programme manager was appointed and a plan to improve the Risk Map's governance was drawn up. Roles and responsibilities were made more explicit. Ever since, the main provincial responsibility for the Risk Map has been borne not by all twelve provinces, but by one provincial deputy, who is a member of the Association of Provinces and acts as owner. In addition, the steering committee of the Association of Provinces changed into a committee with a stronger focus on content rather than financial resources. This centralisation of the Risk Map's ownership endowed it with improved political capital.

On the operational level as well, more structures were added. The provincial shared service organisation improved its change management process by

making it more transparent for the provincial coordinators. Every year, an annual plan is now drafted in collaboration with the programme manager. There are two provincial committees, one on the operational level and another on the tactical level, where collaborative decision making takes place.

The provinces are also trying to involve the two ministries more, as they are still responsible for the Risk Map and its accompanying laws. Renewing the laws is seen as necessary, as some of its contents are outdated. Furthermore, new actors such as the safety regions are now involved, but their legal responsibilities and involvement with the Risk Map are not clear.

The new goal and vision of the Risk Map is to build a new SDI to replace the old legacy system. The new system should be more lightweight and reuse existing data, so providing data would become easier. Another idea is to provide all data as open data, so the authorised part of the Risk Map could disappear. The new Environment and Planning Act, which is a programme to modernise, harmonise and simplify current rules in the Netherlands and improve its data provision by building an SDI, is seen as an opportunity for the Risk Map by some actors, while others see it as a threat.

The Risk Map still faces some major challenges. Support for the Risk Map varies from province to province. Some argue that responsibility for the Risk Map should be transferred to the safety regions. The safety regions are legally responsible for risk communication nowadays, but lack a formal role in the Risk Map. As a result, they now self-organise to build new Risk Map products on top of data and services from the current Risk Map. Also, in many regions, environmental services have taken over the job of data providers from municipalities. This has led to an improvement in data provision, but these environmental services also lack a formal role in the governing system of the Risk Map.

In 2019, a report from the Research and Documentation Centre of the Ministry of Justice and Security (Bongers et al. 2019) concluded that while the roles and responsibilities have been made more clear, the legal and organisational context of the Risk Map still is too complex. More changes to the Risk Map on a structural level seem inevitable.

3.4.1.3. Analysis of the governing system

When we compare the relative frequencies of round 1 codes with those for

round 2, we can see interesting trends (see Figure 3.4). When we look at the image, the collaborative image seems to be less unaligned in round 2 than in round 1. A possible explanation could be that the emergence of the Risk Map's 'governing crisis' sparked more alignment of images. Additionally, more positive feedback is now flowing through the system. However, the satisfaction in both rounds seem to be more negative than positive.

When we look at the interaction patterns, we can see that round 1 has more top-down interventions than round 2. This is easily explained by the order from the national government to create a Risk Map after the fireworks disaster in Enschede. Interplays are the main form of interaction in both rounds. Because twelve provinces have the shared task of creating a Risk Map, this interaction form seems a logical fit.

Coordination is improved in the second round, as a lack of coordination was one of the main concerns in the first round. However, collaboration seems to be better in the first round. From the interviews it appeared that especially the collaboration with and coordination of the national government could be improved. In the second round we also see a decrease in support and trust, which affects collaboration.

Self-organisation is present in both rounds. However, from the interviews it appears that this is not always positive. In many cases, an increase in self-organisation occurs when coordination is lacking or the stakeholder's requirements are not fulfilled. This self-organisation can lead to fragmentation of information and systems.

Although coordination is improved, the codes indicate no strong change either in roles and responsibilities, or in ownership. This can be explained by the fact that roles and responsibilities have been made clearer within the provincial structures; however, the involvement and roles of the safety regions and environmental services remain unclear. Furthermore, many find the dual ownership by two ministries a constraining structure.

Law and standards are also seen as constraining structures in the second round, as many find these out of date. However, the legal framework also acts as a lifeline for the Risk Map; quitting is legally not possible. Another clear constraint is technology, as the current SDI has become too complex to maintain. On the

Figure 3.4. Shift in the governing system of the Risk Map in round 2 compared to round 1, based on the relative frequency of codes.

other hand, there is a strong belief that technology can be an enabler when a new Risk Map system is built.

This relates also to another constraint; the budgetary resources. In fact, there is no shortage of funding for the Risk Map, but many actors think the costs of the current system outweigh its benefits. The greatest share of the budget goes to maintaining the outdated technology. An important condition for the new Risk Map is actors' expectations that its maintenance should be cheaper than that of its immediate predecessor.

The codes about SDI performance qualities give mixed results in every area (data provision, data quality/availability and use). From the interviews and reports, it is clear that data quality has improved slightly over the past years, but that users still cannot fully trust the data.

3.4.2. New Map of the Netherlands

3.4.2.1. Round 1: 1997 – 2010

The New Map of the Netherlands was an idea of spatial planners who required more information to obtain a better overview of the spatial dynamics in the Netherlands. This need for information was not new, as the National Planning Office (*Rijksplanologische Dienst*) in the Netherlands had previously tried to gather statistics about the current and planned building capacity. However, what was new here was the need to spatially locate these plans. First, regional maps with spatial plans were made in Amsterdam and Rotterdam. The idea to do this for the whole of the Netherlands gained a great deal of momentum and the 'New Map of the Netherlands Association' was formed.

Hundreds of urban and spatial planners volunteered in 1997 to collect data and create a map showing what the Netherlands would look like in 2005. The New Map of the Netherlands was widely introduced, gaining much attention from politicians, professionals and the general public. Because of its success, the ambition was to create a 'New Map' every two years, making it possible to look even further into the future.

Meanwhile, around the same time, the National Planning Office also needed a geographical overview of all national plans. Therefore, they made a national map, 'the Netherlands in Plans', not only showing concrete plans for the near future but also 'softer' long-term plans. One of the information sources it used was

the New Map, and in 2003 it was decided that the New Map of the Netherlands would receive a subsidy from the Ministry of Housing, Spatial Planning and the Environment (VROM). The New Map also incorporated the idea of making a distinction between 'soft' and 'concrete' plans.

From then on, the New Map was administered as follows. The Ministry acted as client to the New Map Association. The map itself was executed by an association for spatial planners, NIROV, which hired several employees to call municipalities and scan newspaper articles to collect information about spatial plans. Typically, they had to digitise analogue maps with GIS and fill in the attributes in a standardised manner while working with unstructured plans: a labour-intensive method.

In a way, the organisation was ahead of its time. In 2006, they decided to open all data with a CC-BY Creative Commons license. The association also experimented with new dissemination channels, creating the first web mapping service (WMS) in the Netherlands and a KML file to integrate into Google Earth. Also, the update frequency was speeded up from releasing a New Map every two years to updating it every month.

However, the New Map did not fulfil all information needs. As decentralisation continued, spatial planning in the Netherlands became less of a national affair and provinces became responsible for keeping an eye on all municipal plans. The province of North Holland noticed that the New Map was mainly spatially focussed; it therefore developed its own monitoring system, which included also statistical aspects of new residential areas. The advantage of this system was that it directly involved municipalities as data providers, giving the data a more authoritative character. In 2009, the province of South Holland developed a similar system, which they later also opened up to other provinces in the Netherlands.

In 2010, due to the economic crisis, the Ministry of Housing, Spatial Planning and the Environment had to cut its budget and decided not to fund the New Map anymore. By suspending its payment for the labour-intensive data collection, the Ministry could easily save one million Euros per year. Furthermore, it was argued that because of the decentralisation of spatial planning, involvement of the national government was no longer needed. A digital system for legal zoning plans was also introduced in 2008, already giving a much better overview of

spatial dynamics in the Netherlands.

The decision to stop funding the New Map was a hard one for the association. Together with civil servants, they tried to find other organisations to support the New Map, but they did not succeed as those organisations were wary of the costs. Furthermore, the economic crisis had slowed spatial planning down and caused house prices to drop dramatically, and there were great doubts that matters would improve. Without any funding, the association and the New Map of the Netherlands itself had to cease operations.

3.4.2.2. Round 2: 2010 – Now

Several initiatives started to bring the New Map back to the political agenda. In 2011 a study on behalf of the national government showed the need for more information about spatial planning and set up ideas for a new, affordable, official monitoring system. From the findings, it became clear that almost every province was already collecting information about building plans for residential purposes, although their approach differed. However, no follow-up study was commissioned to centralise these different systems.

Meanwhile, the monitoring systems of the province of North Holland and South Holland were in place, which raised interest from the other provinces. A study was performed to decide which of these two monitoring systems was a better fit for the other provinces' purposes. It was decided that the South Holland system would be better, as it used open standards and open source software. Six of the Netherlands' 12 provinces joined the system of South Holland, while the North Holland system was adopted by two provinces. The province of Limburg created its own system. The remaining three provinces of the Netherlands do not have a monitoring system for spatial plans.

In 2016, an independent National Government advisor on the Built and Rural Environment took the initiative to collaborate with the two owners of the North and South Holland systems. The three founders organised themselves into an association and launched the 'New New Map of the Netherlands' in 2018. The initiative gained support from several users, among them the Ministry of the Interior (nowadays responsible for spatial planning) and the Netherlands Environmental Assessment Agency. Both provide the association with some funding in exchange for participation in the association.

Combining the data of the two provincial systems made it possible to create a map with plans of approximately half the country. However, municipalities can choose for various reasons to restrict access to their plans, and deny access to the public. Therefore, data for only a small part of the country are available to the public. The current challenge is to convince other municipalities and provinces to voluntarily release their plans. One instrument the association uses is to make the data provision as easy as possible, by allowing provinces to use their own data model. The association then manually transforms the data by itself and adds it to the *New New Map*.

3.4.2.3. *Analysis of the governing system*

When the decision was made to stop producing and disseminating the New Map, the governing system of the New Map of the Netherlands changed drastically. When we compare the relative frequency of codes from round 1 to round 2 (see Figure 3.5), we see a decrease in most aspects regarding the organisation of an SDI, such as an explicit image (goal/vision), the action 'coordination', the instrument 'rule' and structures such as 'roles and responsibilities', 'standards' and 'ownership'. When we look at softer aspects, we also see in the second round that images are less aligned and there seems to be less trust. Also, the data quality/availability and use seem less.

Interestingly, support for the SDI and data provision is increased, as well as decreased. This is all explained by the fact that in every interview, the candidates mentioned the challenge of convincing all provinces and municipalities to open up and provide their plans. While there are clear and supportive advocates and data providers, at this moment the *New New Map* covers less than half of the Netherlands, which makes data availability one of the main challenges for this SDI.

Somewhat surprisingly, technology also seems to be more constraining in the second round than in the first. This can be partly explained by the fact that both owners of the current provincial systems point out the drawbacks of their system. Furthermore, in the first round, the New Map was embracing new technologies and seemed ahead of its time in its dissemination channels.

Still, not everything has decreased in comparison with the first round. The codes indicate a relative increase in leadership, self-organisation and social capital. Not surprising is the fact that in both rounds most codes in the category 'action'

round 1, based on the relative frequency of codes.

are about self-organisation, as the New Map is in both rounds a product of self-organisation. Interestingly, budget resources have become less enabling but also less constraining. This can be explained by the fact that the budget for the *New New Map* has been greatly trimmed—some estimate that the current costs are ten times lower—while it is a much greater challenge to raise enough money from supporting organisations than it was during the years of stable financing from the ministry.

It is clear that the governing system of the New Map of the Netherlands has become much more vulnerable in the second round. This is not surprising, as the current SDI is almost completely based on a self-organising network of professional volunteers, with virtually no structures. Although making the SDI vulnerable, this approach also generates goodwill and support, as many interviewees argued that a legal, top-down approach would probably not benefit this SDI in view of the uncertainty and unofficial character of the plans. As the *New New Map* initiative is very young, only time will tell how successful this SDI could be. It is clear from its own predecessor that from a self-organised SDI, a more structurally embedded SDI can emerge.

3.5. Discussion and Conclusion

This study has attempted to understand SDI governance dynamics by means of a thorough analysis of the governing system. With the help of the governing system framework, more insights into the strong and weak aspects of the governing system became apparent. By comparing governing systems of an SDI over time, changes in the governing system appear. This could be a helpful analytical tool for SDI governors who want to assess the governing system of their SDI. For our research, we used a thorough analysis based on documents and interviews. However, with some modifications the framework can perhaps also be used for quick scan purposes or in combination with other data collection methods.

For analytical purposes, we divided the cases into rounds to analyse the governing system. For the New Map, which experienced a sudden stop, this time interval seems to fit. However, for the Risk Map, which gradually evolved into a crisis situation and also incrementally tried to break away from it, a finer-grained time interval would probably give even more insights into changes in the governing system. Longitudinal research which assesses the governing system

of an SDI year by year would be a revealing topic for complementary study.

One drawback of our focus on the governing system only is the fact that external factors are not taken into account. These external factors are unpredictable and beyond the control of the actors in the governing system, but in both case studies we see that external factors actually seemed at least partly responsible for the crisis situation in the governing system. As a result of changes in the political and economic system, it was decided to stop funding the New Map. Similarly, the decision to reorganise the safety and disaster system in the Netherlands caused problems for the Risk Map, whose organisation remained largely based on the old system. Like other complex adaptive systems, this openness and sensitivity to external factors is a feature of SDIs (Grus, Crompvoets, and Bregt 2010), but this does not make SDI governing an easy and predictable job.

In this respect, it is interesting that many involved interviewees imagine a future where multiple SDIs and datasets are connected. In both case studies, an important future goal is to diminish data providers' effort by reusing existing data and connecting data to other datasets and SDIs. Spatial data provision is evolving from central to decentralised, towards an ecosystem of spatial and non-spatial data infrastructures where both centrally and non-centrally provided data resides. Not only governments, but also the private sector and citizens play a pivotal role in this ecosystem as users and/or producers of data (Budhathoki, Bruce, and Nedovic-Budic 2008). In this way, data collection and sharing becomes more efficient and inclusive, but the SDIs will also be more sensitive to and dependent on each other's changes, which increases the complexity of their governance.

The proposed governing system framework gives another viewpoint for looking not only at SDIs, but also at existing SDI frameworks. For example, the five classical SDI components of Rajabifard, people, data, standards, access network and policy (Rajabifard, Feeney, and Williamson 2002), fit in the governing system framework. Standards, access network (or technology) and policy are important enabling structures for data sharing between people. However, these SDI components are not always SDI enablers, as the case studies in this research point out. Additionally, other SDIs such as INSPIRE suffer from overly fixed structures such as standards (Borzacchiello, Boguslawski, and Pignatelli 2018), which could provide a risk for its support.

Analysing the governing system of an SDI with the framework used here seems a useful method to better understand the governance and governability of an SDI. Two weaknesses are that it does not give insights into causalities and it does not encompass external effects, which could have a major influence on SDIs. Moreover, with the qualitative method we used, we can only make comparisons between rounds within the case study itself. Comparisons between different SDIs would appear difficult. By applying the governing system framework with a more quantitative approach, such as surveys, the framework could be a useful tool for SDI governance benchmarking.

However, the two case studies in this research show that the combination of qualitative analysis and the governing system framework is a valuable tool for understanding SDI governance dynamics. With the help of the proposed governing system framework, shifts and trends become visible, while the qualitative analysis helps to give meaning to these SDI governance dynamics. As these two cases were goal-oriented SDIs, the governing system framework must be applied to other types of SDIs and SDI contexts in order to provide proof of its full potential.

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Chapter 4

Governance Interactions of Spatial Data Infrastructures: An agent-based modelling approach

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Abstract

In order to facilitate and coordinate spatial data sharing and exchange, many organisations have developed spatial data infrastructures (SDIs). SDI governance plays a pivotal role in the development and evolution of an SDI, but as SDIs are complex adaptive systems, governing is a challenge. This research therefore proposes a complexity perspective to SDI governance by exploring the use of agent-based modelling to simulate and examine SDI governance interactions. In this agent-based simulation, we examine interactions between SDI stakeholders, data availability and the effects of different governance styles (hierarchical, network and laissez-faire governance) and budget policies. The simulation shows that it is possible to mimic SDI governance dynamics through agent-based modelling. By running different scenarios, it appears that a network approach is more successful compared to a hierarchical or laissez-faire approach. Expert validation shows that overall the results of the simulation are credible and insightful, although improvements can be made to make the model more realistic. With agent-based modelling, SDI governance becomes more tangible and visible, which facilitates discussion and understanding. Agent-based modelling therefore appears to be a helpful new approach in a better understanding of the complexities and dynamics of SDI governance.

Keywords: governance; spatial data infrastructure (SDI); agent-based modelling; funding models; complex adaptive systems.

4.1. Introduction

In the past decades, many organisations developed spatial data infrastructures (SDIs) to facilitate and coordinate spatial data sharing and exchange (Crompvoets et al. 2004). Although originally, SDIs were established to enable spatial data sharing between - mainly - public organisations, nowadays many organisations have decided to open up their spatial data to anyone, resulting in open spatial data infrastructures (Vancauwenberghe and van Loenen 2018).

With growing SDI use, also the group of SDI stakeholders is growing. This generates more benefits, but also tensions. SDI stakeholders can have conflicting needs and interests. What facilitates achieving the objectives of one group of SDI stakeholders, can be counterproductive in achieving objectives of others (Hendriks, Dessers, and van Hootegeem 2012). To maintain the delicate balance between all stakeholder interests, setting up an SDI governance framework is crucial, but also a challenge (Coetzee et al. 2018).

SDI governance is a complex and dynamic process. SDIs are acknowledged to behave like complex adaptive systems where *'features and behaviours such as openness, level of self-organisation, adaptability and existence of feedback loop mechanisms, play an important role in the efficient and effective functioning of SDI'* (Grus, Crompvoets, and Bregt 2010, p.457). Governing complex adaptive systems is challenging, as surprises, threshold and cascading effects occur (Duit and Galaz 2008). In governance, solutions to problems can lead to new problems (Verhoest, Bouckaert, and Peters 2007) or undesired effects (Kooiman 2003). Case studies on SDI governance (Sjoukema, Bregt, and Crompvoets 2017; Sjoukema, Bregt, and Crompvoets 2020) show that 'tipping points' or 'crucial decisions' in SDI governance also definitely occur, which can influence the development and evolution of the SDI considerably.

Complexity of a system emerges from local interactions among individual entities (Manson, Sun, and Bonsal 2012). As both governance and SDIs exist of many local interactions between involved stakeholders, it is not surprising that both governance and SDIs are seen as complex subjects. Despite this fact, in general research on SDIs and SDI governance tend to focus on SDI components (e.g. Hendriks, Dessers, and van Hootegeem 2012; Vandenbroucke et al. 2009) or SDI governance instruments and structures (e.g. Vancauwenberghe and van Loenen 2017; Crompvoets et al. 2018; Sjoukema, Bregt, and Crompvoets

2017). This is not surprising, as these are the more tangible appearances of SDIs and SDI governance. Social network analyses (Vandenbroucke et al. 2009; Coetzee et al. 2018; Coetzee et al. 2019) help to give insights in the broad range of interacting SDI actors, but it is difficult to identify from these analyses the dynamics and emergent phenomena. SDIs are emergent phenomena, as their properties are wider than the sum of their parts (components) (Bonabeau 2002; De Man 2006).

A method which is suitable to reproduce emergent phenomena by programming local interactions is agent-based modelling. With agent-based modelling complex macro level behaviour can be mimicked by simulating micro level interactions (Manson, Sun, and Bonsal 2012). *'Even a simple agent-based model can exhibit complex behaviour patterns and provide valuable information about the dynamics of the real-world system that it emulates'* (Bonabeau 2002, p.7280). It is therefore a promising method for understanding SDI governance as *'the stronger any interaction effects are, then the more important it will be to consider agent-based or other disaggregated approaches'* (O'Sullivan et al. 2012, p.119). Other advantages of agent-based modelling are that it is flexible, provides a natural way to describe systems and makes complex systems more tangible (Bonabeau 2002).

Although agent-based modelling is often applied in the field of geo-information science, it has not been used in SDI research until recently: Lubida et al. (2020) show in their study on the Tanzanian NSDI that agent-based modelling can be an useful method to better understand the process of SDI development.

Craglia et al. (2012) argue that SDIs lack in general multi-disciplinary models for forecasting change, thresholds and tipping points, that they do not include scenarios of possible policy responses and lack participatory frameworks to engage decision-makers. We think that this does not only apply to the services SDIs provide but also to the way SDI governance is performed and understood. Agent-based modelling can help to overcome these challenges.

A possible reason why agent-based modelling is hardly used for SDI governance, is the fact that SDIs exist of many interrelated components and are always unique, which makes it hard to distinguish all influential local governance interactions and mechanisms. As a model is always a simplification of reality, developing an agent-based model asks for the right balance of complexity: *'If the level of*

abstraction is too simple, one may miss the key variables. Too much detail, and the model will have too many constraints and become overly complicated' (Crooks and Heppenstall 2012, p.98). In general there seems a tendency to favour simple agent-based models over complex models as complex models will be equally difficult to understand as the real world phenomena. The aim of an agent-based model should be to represent the key features in a particular context of a system in order to enable us to improve our understanding of how that system works (O'Sullivan et al. 2012).

The objective of this research is to simulate and examine SDI governance dynamics using agent-based modelling. We do this by developing a generic agent-based model which simulates local SDI governance interactions. These local governance interactions should be adjustable in order to apply different governance styles and policies. The model should provide insights to SDI stakeholders in which governance strategies are the most effective. By discussing the simulated model and its results with SDI experts, the added value of an agent-based modelling approach to the field of SDI governance can be determined.

The first step in agent-based modelling is to develop a conceptual model. The following section therefore will operationalise these interactions further and summarise it into a conceptual model. In the third section the method for model development is explained. Section four explains the model simulation results. Section five discusses the use of agent-based modelling for SDI governance, its limitations and the possibilities for future research. The last section concludes this research.

4.2. SDI governance concepts

Governance is the process of governing in which multiple actors (both public and private) participate to influence this process through interactions. Interactions are a key element in governance, which does not only apply to interactions between actors, but also between actors and the structures they are bound to. Actors, structures and interactions are therefore considered as the basic aspects of governance (Figure 4.1) (Kooiman 2003; Sjoukema, Bregt, and Cromptvoets 2020).

The governance process works as follow: Actors define and shape problems they want to solve based on their perception or 'image'. In order to solve problems,

Figure 4.1. Actors, interactions and structures (Sjoukema, Bregt, and Cromptoets 2020).

they are interdependent of other actors, who need to, for example, change their behaviour or help the governing actor. To steer another actor into the desired actions, governing instruments are used. A wide variety of instruments can be used, ranging from ‘soft’ instruments such as information sharing towards ‘hard’ instruments such as laws and punishments. These instruments are applied into action which will affect the other actors. These actors will respond by giving either indirect or direct feedback, which can be both positive and negative. This interactive day-by-day process is also what we can call the ‘actor level’ of governance (Kooiman 2003).

Structures, such as institutions, cultures and resources, enable and constrain these actors and interactions. These structures are stable in the short term, but can be changed in the long term (Giddens 1984). Through interactions, actors communicate with other actors or try to change the structures they are bound to (Kooiman 2003).

We apply this framework onto SDIs and try to simulate how the actors and the state of the SDI influence each other. To limit the complexity of the model, we chose to simulate the following SDI governance interactions, to see how they influence the course of an SDI:

- Interactions between SDI actors themselves, depending on various governance styles (hierarchical, network and laissez-faire)
- Interactions between SDI actors and the SDI
- Interactions between SDI actors, the SDI and their structures (resources)

The following section describes the actors, interactions, structures and the SDI which together shape the conceptual model used for simulating SDI

governance. To gain a full understanding of the complete agent-based model, an ODD (Overview, Design concepts and Details) is added as Appendix D (Grimm et al. 2010).

4.2.1 Actors

Most SDIs have a large diversity of actors or stakeholders. And with open SDIs, these actors can be virtually everyone. Several SDI scholars have tried to define SDI actors and their roles (e.g. Hjelmager et al. 2008; Richter, Miscione, and Georgiadou 2010; Coetzee et al. 2018). In this research we use a 'geographic data flow' perspective on the SDI (Richter, Miscione, and Georgiadou 2010), which connects well to the network perspective described by Vandenbroucke et al. (2009). In this network perspective, actors act as nodes on a network. Producers and users of spatial data are nodes in this network, as well as coordinating bodies and stakeholders who process and facilitate the spatial data infrastructure (Vandenbroucke et al. 2009). In total we identified four important SDI actor roles:

1. *SDI executive*: This actor role represents the executive branch of government that has authority and responsibility for the SDI. In many cases, the SDI executive has the role of 'policy maker' or coordinator, and determines the mission and vision of the SDI. The SDI executive is in many cases the most influential actor in SDI governance (see e.g. Coetzee et al. 2018; Coetzee et al. 2019).
2. *SDI data providers*: This actor role represents the organisation(s) who delivers spatial data to the SDI. It can also be seen as data producer.
3. *SDI platform provider*: This actor role represents the organisation(s) who maintains and updates the infrastructure and plays a central role in bridging data from SDI data providers to SDI users. It can have the role of provider or broker.
4. *SDI users*: This actor role represents the organisations(s) who uses the spatial data from the SDI. SDI users use spatial data as end-user or as value added re-seller.

In the model, the four actor roles should be seen as aggregations of the total group they represent as in practice, an SDI never exists of four actors. In general this applies foremost to the SDI data providers and users, but also the role of SDI executive or platform provider can be shared by multiple actors in practice. Also, an organisation can take multiple roles, for example as data provider and as user. However, to better understand the dynamics and interactions of the

agent-based model, we deliberately choose to limit the number of agents to four actor roles.

The actor's image is an important starting point in governance. A positive image of the SDI will lead to a more used and trusted SDI, while a negative image will lead to the opposite effect. A negative image can also influence the SDI negatively as Coetzee et al. (2018) note that: *'it is highly unlikely that providers of local data will bring up the energy and resources to implement something that has only indirect or longer-term benefits for them'* (Coetzee et al. 2018, p. 17). Within an SDI, images of actors do not have to be aligned with each other. In the model, all actors own the attribute 'satisfaction'. This represents their overall satisfaction with the SDI and its governance in a broad sense.

4.2.2. Interactions

One of the core principles of governance is that every involved actor can influence the governance process. However, it depends heavily on the governing position of the actor and her/his resources what kind of governing instrument it can choose (Kooiman 2003). For example, in many cases it is the SDI executive who can make legally binding policies around an SDI. An SDI user can also influence the course of the SDI, by giving feedback, taking part in user committees or providing information on how the data is used. However, a user will not have the power to use any 'hard' instruments.

In the model we therefore make a distinction between three types of instruments:

- Hierarchy messages, representing the use of hierarchical instruments
- Network messages, representing the use of network instruments
- No messages, representing a laissez-faire approach: no instruments are used

In our model, only the SDI executive has the power to use hierarchy messages which resemble the 'hard' instruments. In practice this can translate to decisions on standards, policies, laws and allocation of tasks and responsibilities (Vancauwenberghe and van Loenen 2017). In the model, every actor has the ability to send network messages representing the 'soft' instruments. A no message resembles the act of doing nothing, as choosing to do nothing can also influence the governing process.

Feedback loops are an essential part of complex adaptive systems (Grus,

Crompvoets, and Bregt 2010). In the model, the actor who receives the message will respond with feedback. Whether this feedback is positive or negative, depends on the history of sent messages to an actor. Actors in the model prefer a mix of messages as Edelenbos et al. (2015) notices that *'continuously steering towards interaction, participation and consultation tends to produce inertia; over-emphasis on hierarchical top-down control has the disadvantage of driving parties to dig in their heels, leading to resistance, delays and postponements of implementation'* (Edelenbos et al. 2015). Mixing governance styles seems also a prerequisite for adaptive governance (Dietz, Ostrom, and Stern 2003). Therefore, in the model, when an actor gets too many similar messages in a row, the satisfaction of this actor decreases and the actor responds with negative feedback.

4.2.3. Structures

Structures, such as policies, laws and resources enable and constrain the governance process. Standards, technology and policies are not only key components of an SDI (Rajabifard, Feeney, and Williamson 2002) but also examples of SDI structures. Resources, such as monetary, but also knowledge, time, social and political capital are also essential structures as they influence the choice for instruments (Sjoukema, Bregt, and Crompvoets 2020).

As resources are also necessary to produce and maintain spatial data and the SDI itself, we limit the structural level in the model to budgetary resources and resource allocation policies. This does not mean that other types of structures are not important to SDI governance, but resources add an extra dynamic dimension to the interactions where for example standards, laws and policies are more static in the short term.

Producing spatial data and maintaining an SDI are costly endeavours. The data providers and SDI platform provider are in many cases the actors who are making these costs. SDI users will benefit from the data and services the SDI delivers. There are multiple funding models for SDIs and their data (see e.g. Welle Donker and Van Loenen 2016). In the model we will simulate three: piecemeal funding, continuous funding and pay-per-use funding.

- *Piecemeal funding:* With piecemeal funding, budget is provided without a coherent long term vision or strategy, for example by projects. Literature on early SDIs shows that many SDIs are funded by a

- piecemeal approach (Crompvoets et al. 2004).
- *Continuous funding*: With continuous funding, there is a stable flow of budget covering the main costs of the SDI. According to Crompvoets et al. (2004): 'It seems that the stability of funding has a positive impact on people's use and management and of the quantity of the data' (Crompvoets et al. 2004, p.682).
- *Pay-per-use funding*: In the previous two financing model, resources were gained and allocated through the central governing actor, the SDI executive. In this model, not the SDI executive but the SDI users will recover the costs of the SDI data provider and SDI provider by paying for the data if the quality is good enough.

4.2.4. Conceptual model

Figure 4.2 summarises the conceptual model which is used for the agent-based model. It shows the four actors (SDI executive, SDI data providers, SDI users and SDI platform provider) and the way they interact. All actors can send each other messages and respond to the received messages with feedback.

Figure 4.2. Conceptual model showing the interactions in the SDI Governance model.

The SDI is represented by a data flow, streaming from the SDI data provider through the SDI platform provider to the SDI user. One of the main objectives of the first two actors is to keep the quality of data good enough in order to satisfy the SDI user. In order to provide a good data flow, the SDI data providers and SDI platform provider have to spend resources and should be satisfied. Depending on the budget policy either the SDI executive (continuous and piecemeal funding) or the SDI user (pay-per-use funding) recover these costs.

4.3. Method

This section describes the model development, its workings, the process of verification and validation and the formation of scenarios for applying the model. For a full model description following the ODD (Overview, Design concepts and Details) protocol (Grimm et al. 2010), we refer to Appendix D.

4.3.1. Model development, setup and working

The agent-based model was iteratively developed based on the described theoretical concepts, with the help of the agent-based modelling software NetLogo version 6 (Wilensky 1999). By starting small and iteratively extending the model, the working of the code could directly be tested. As the model developers and the authors of this research are the same, miscommunication risks were prevented.

Before initialising the agent-based model, the user can influence five inputs. The first three are the probability on a certain type of message (hierarchy, network or no messages) on a 0 to 100% scale. As in the model there is an equal chance for each message type to be selected, setting them all to the same percentage will result in a 1/3 chance of a certain message. However, by setting each input to a different ratio, it is possible to make a certain message type more dominant.

Another input is actor's susceptibility to feedback. In reality, not every actor will either send explicit feedback or listen to received feedback. We added therefore in the model an input called susceptibility to feedback on a 0 to 100% scale. By changing this ratio, the influence of feedback in the model can be altered.

The last input which can be influenced by the user is the budget policy, which can be set to continuous, piecemeal or pay-per-use financing. With the continuous

budget policy, funding is provided and allocated from the SDI executive to the SDI data and platform provider every time step. With the budget policy set to piecemeal, every 5 time steps budget is provided to the SDI executive, while this actor keeps the role of allocating resources at every time step. In the pay-per-use budget policy, the SDI user pays the SDI data and platform provider if the data quality is good enough.

When running the model, first a message type and an actor are selected. Then this actor chooses randomly another actor to send her/his message to. The receiver compares this message with previously received messages and changes her/his satisfaction. Basic principle is that the satisfaction of the receiver decreases when she/he gets three times in a row a network or no message or two times in a row a hierarchy message. However, a single hierarchy message boosts the satisfaction more than a single network message. A single no message has no positive or negative effect. Based on the receiver's change in satisfaction and her/his current satisfaction, feedback is sent. Depending on the susceptibility to feedback settings, this feedback affects the satisfaction of the original sender.

Budget is allocated to the SDI data provider and SDI platform provider. They need to be satisfied and spend resources to maintain the quality of the data flow. When the quality is good enough, the SDI user will increase her/his satisfaction and gain resources. When the quality is poor, the SDI user will give negative feedback to the SDI data provider and SDI platform provider. They will then spend extra resources to improve the quality.

The model runs until the average satisfaction of all involved actors is below 1 on 0 to 10 scale: the SDI and its governance interactions have then failed to satisfy its stakeholders.

4.3.2. Verification, Calibration & Validation

Verification, the process of comparing the agent-based model to the conceptual model and its behaviours, is important for any agent-based model (Rand and Rust 2011). We took several steps to verify the model. At each iteration of the model development process, the model was manually tested in order to see if the dynamics behaved according to the theoretical conceptions. From the first developments onwards, the model was continuously verified and documented in both the code and the ODD protocol.

We used relative value testing and sensitivity analysis to test the model (Rand and Rust 2011; Ngo and See 2012). With relative value testing, we tested if the chances on message types (hierarchy, network, no message) which can be influenced during model initiation, corresponded with the distribution of messages as output. During sensitivity analysis, the model was run 1000 times while chances on a certain message-type were increased step by step with 5%, while all other message inputs were held stable at 50%. This was also done for the susceptibility to feedback input. In this way, it was assessed if there was any unexpected behaviour. When necessary, the model was altered and the tests were run again. We ran the model 1000 times in order to gain robust results. Section 4.4. discusses the final results from the sensitivity analysis.

At the final stage, the model was validated through expert judgement (Bonabeau 2002). First, the conceptual model, the agent-based model and its underlying concepts were shown and assessed individually by SDI governance experts to validate the micro-level behaviour of the agents and its interactions (micro-face validation). Thereafter, the outcomes and the emergent macro-level dynamics were shown and individually assessed by these experts (macro-face validation (Rand and Rust 2011)). Empirical validation was not used, as the model should be seen as a generic exploration of SDI governance dynamics instead of a model which resembles any particular reality with an SDI governance case.

Four online expert sessions were organised in 2020 where first the face-validation was done individually and thereafter a panel discussion was followed to discuss the model, the outcomes and its usefulness. The consulted experts have different backgrounds, either in practice with experience in at least one SDI role (executive, data provider, platform provider or user) or as an SDI governance researcher. In the first session among Dutch experts, it was argued that the validation would become stronger if also experts from a different cultural and institutional background participated. Therefore, also Dutch speaking experts from Belgium were invited, as they bring a different background while the questions could remain the same, which prevents possible misinterpretation due to translations. In total 18 SDI governance experts, 5 from Belgium and 13 from the Netherlands, were consulted. In Appendix C the questions and results are shown.

4.3.3. Scenarios

As we want to examine the effect of different governance interaction styles on the performance and sustainability of SDI governance, three scenarios were drafted. In each scenario a different message type is dominant:

1. Hierarchy scenario: A scenario with a relative high chance of hierarchy messages (70%), while setting the network and no message types relatively low (30%).
2. Network scenario: A scenario with a relative high chance of network messages (70%), while setting the hierarchy and no message types relatively low (30%).
3. Laissez-faire scenario: A scenario with a relative high chance of no messages (70%), while setting the hierarchy and network message types relatively low (30%).

4 The reason to choose for a 70/30/30 setting for each scenario, is the fact that we want to compare the performance and sustainability of each scenario. When we use less extreme settings, the results become less distinct. Because of chances and random factors in the model, chances rise that another message types than the message type with the highest setting becomes dominant. However, when we choose a more extreme setting, the scenarios become too much determinant by one message type and therefore less realistic.

From the sensitivity analysis (see section 4.4.1) it appeared that setting the susceptibility to feedback to 100% gave the best performance, while 0% gave the worst. During simulation of the scenarios we fixed this setting to 75% as 100% did not feel realistic, while a lower setting could influence the dynamics emerging from sending the messages too much.

The governance style scenarios were run with the budget policy set to continuous financing as this policy proved to give the most stability to the simulation. Thereafter, we ran the other two budget policy scenarios (piecemeal and pay-per-use) to analyse if these budget policies affect the interaction and course of the SDI positively or negatively.

Like almost all agent-based models, also this SDI governance model shows stochastic behaviour (Rand and Rust 2011). This manifests itself in the fact that ultimately the SDI governance failed in all simulations, although the duration of the simulation varied heavily. Even in the best performing scenario it could

happen that the SDI governance failed quickly. This is not wrong as in reality there does not seem to be a golden recipe for SDI governance and with bad decision making, all SDIs can fail. Also in practice, it seems natural that SDI governance renews itself after 10 to 20 years (Sjoukema, Bregt, and Cromptvoets 2017; Sjoukema, Bregt, and Cromptvoets 2020).

To get reliable trends from the scenarios despite the stochastic behaviour, we ran each scenario 1000 times. As the average SDI life span still could be skewed because of the fact that some runs took a very long time, while others failed quickly, we also ran the scenarios with a fixed amount of time steps set to 70. Then we looked at their success/fail ratio: how many runs per scenario hit the fixed time period and how many runs failed earlier? In this way we can determine the chance for a successful run in a certain setting.

4.4. Results

This section describes and discusses the simulation results. First it discusses the sensitivity of the model to the various inputs. Thereafter, the outputs from the different governance and budget scenarios are described.

4.4.1. Sensitivity analysis of the SDI governance model

In order to get a feeling of the emergent behaviour of the model, a sensitivity analysis is done. By varying one input setting with incremental steps of 5%, while holding the other inputs stable, the effects of that particular input can be determined in relation to the average number of time steps it took, before the model run failed.

Figure 4.3 shows the average duration in time steps of the SDI governance model, while increasing the susceptibility to feedback with a 5% step from 0 to 100%. This indicates that with an increase in actor's susceptibility to feedback, SDI governance will last longer. 100 percent, meaning all feedback is always considered, leads to the longest SDI governance life span. In practice, it is not realistic that feedback is always directly given or properly addressed, but the positive effect of feedback loops is a clear outcome of this model.

An incremental increase of 5% of the chance of a certain message type also affects the outcome of the model as is shown in Figures 4.4 till 4.6. Hierarchy messages help the SDI governance model to increase its sustainability. However, only in small amounts as after the 30% the average performance decreases as

Figure 4.3. Relation between an increase in the susceptibility to feedback and the average life span of the SDI.

Figure 4.4. Relation between an increase in the chance of hierarchy messages and the average life span of the SDI.

Figure 4.5. Relation between an increase in the chance of network messages and the average life span of the SDI.

Figure 4.6. Relation between an increase in the chance of no messages and the average life span of the SDI.

is shown in Figure 4.4. Figure 4.5 shows that the life span increases when the chance of network messages becomes higher. However, this result also shows that governance existing of only network messages would not be preferable, as the life span peaks around the 70% chance. Thereafter, an increase of network messages does not seem to have much effect anymore and the average duration even slightly decreases. An increase of the chance of no messages brings a less clear trend to the SDI governance performance (Figure 4.6). It is clear that above 35% it brings a positive effect, but the course is more capricious. This is not surprising as the no message indicates an absence of governance instruments and thus the SDI governance is still dependent on how the network and hierarchy messages evolve themselves.

4.4.2. SDI Governance scenarios

The results from running the three predefined governance style scenarios

Figure 4.7. Average lifespan of SDI per different type of SDI governance scenario.

Figure 4.8. Success and failure ratio per different type of SDI governance scenario. Success is defined as running for 70 time steps or more.

(hierarchy, network and laissez-faire) are presented in Figure 4.7 and 4.8. Figure 4.7 shows that with an average life span of 100, the network scenario performs the best. With an average of 38 time steps, the hierarchy scenario performs the worst. The laissez-faire scenario performs slightly better and has an average of 45 time steps.

This does not mean that the laissez-faire and hierarchy scenario always result in a failure. Figure 4.8 shows the percentage of runs per scenario who hit the 70 time steps. It shows that 11% of the hierarchy scenario simulations and 19% of

the laissez-faire approach hit this milestone. Also slightly more than half (55%) of all network scenario simulations run longer than 70, indicating that also the network scenario still has a high share of fairly short runs (45%).

4.4.3. Influence of budget policies

We simulated three types of budget policies: continuous, piecemeal and pay-per-use. Figure 4.9 shows how the budget policies affect the average life span per SDI governance scenario. The graph shows that both the continuous and pay-per-use financing are quite successful. From Figure 4.10 it appears that the continuous financing has a slightly higher success rate for the network

Figure 4.9. Average life span of SDI governance per budget policy scenario.

Figure 4.10. Success and failure ratio in different types of SDI governance per budget.

and laissez-faire scenario. It indicates that the pay-per-use policy can be very sustainable, although the stability of the continuous budget policy generates a more stable success. In all scenarios, the piecemeal budget policy is the worst performing scenario.

In general we can conclude that, in this model, the lifespan of the SDI is more affected by the interaction mix than by the budget policies. This can be explained by the fact that the differences in the budget policies are perhaps less extreme as the differences between the three governance style scenarios.

4.4.4. Expert judgement

The inputs, interactions, results and also the model were shown to 18 SDI experts for micro and macro-face validation. Figure 4.11 till 4.14 show the outcomes of four main questions. All questions and results are given in Appendix C. The experts agreed that the actor roles in the model are also the predominant roles that can be found in a real SDI (Figure 4.11). Especially the behaviour and interactions of the SDI platform provider was positively reviewed. The behaviour and interactions of the SDI executive gave the most mixed results although 10 experts found it realistic. Experts were the least outspoken on the behaviour of the SDI user as 10 found it not realistic/unrealistic.

From the various types of interactions (interactions between actors, interactions between actors and budget and interactions between actors and the SDI), the

Figure 4.11. Expert responses (N=17) to statement: 'The actor roles in the model are also the predominant roles you find in a real SDI.'

Figure 4.12. Expert responses (N=18) to statement: 'The outcomes of the governance style scenarios provide more insight in SDI governance.'

Figure 4.13. Expert responses (N=18) to statement: ‘The outcomes of the budget policy scenarios provide more insight in SDI governance.’

Figure 4.14. Expert responses (N=18) to statement: ‘Considering all aspects, this model is useful for gaining more insight in SDI governance.’

interactions between actors and budget were the least positively reviewed. Experts explained that the SDI data provider does in many cases not get directly budget from the SDI executive. In fact, the SDI data provider has to pay the SDI platform provider in many cases the costs for hosting their data. Also experts explained that in reality, several mixes of budget policies exist (e.g. part is covered by the central government, part is covered by pay-per-use policy).

When looking at the results from the three governance style scenarios, 13 experts agreed that they were credible and provided more insight in SDI governance (Figure 4.12). Again, the budget scenarios (Figure 4.13) scored less compared to the governance style scenarios, although also 10 experts agreed that these outcomes were credible and 12 agreed that they provided more insight in SDI governance. Considering all aspects, 13 of the 18 experts found the model useful for gaining more insight in SDI governance (Figure 4.14). However, during discussion also some key remarks came from the experts. The next section will discuss these and identify next steps for an agent-based model on SDI governance.

4.5. Discussion

With the agent-based model, experts found that SDI governance became much more vibrant and visible compared to an average policy document. Multiple SDI experts also stated that it directly makes you think about SDI governance in a

different perspective and that it provokes discussion. They saw that potential application areas of the model are in exploring and discussing SDI governance for SDIs on crucial decision moments. When discussions arise about which direction to take, the model can be used to explore possible futures and their dynamics. It can therefore be seen as an important 'discussion support tool'.

Many experts found the results on budget policies especially interesting. Currently, both in Belgium and the Netherlands, open data has become successful, but the increased costs also put pressure on the way it is financed. The fact that the piecemeal scenario performed the worst did not surprise the experts. However, it was surprising that the pay-per-use budget scenario performed almost equal to the continuous budget scenario, as the pay-per-use scenario depends heavily on a proper data quality. This can be interpreted as an argument against open data, but as the model does not give insights in the outreach and benefits of the data this cannot be concluded. However, it does indicate that a pay-per-use budget policy can generate a sustainable flow of resources, supporting the SDI. Sustainable business models on open data tend to incorporate aspects where a part of the users have to pay (Welle Donker and Van Loenen 2016). By adding more and hybrid business models to the agent-based model, it can become a useful tool for exploring sustainable funding models for SDIs and open data.

From the results on the governance style scenarios, the network scenario with continuous financing performs the best. Experts agreed that network governance is probably the best governance mode, but questioned if this result is culturally biased as the model is developed and validated in a mainly Dutch context, where traditionally a lot of consensus building and network governance is dominant (Meuleman 2010). For this reason, also Belgian experts were included in the analysis who bring a different cultural and contextual perspective. However, their valuation of the model did not differ. In general, there has been a shift noted in governance literature towards the current focus on network governance which makes this also a more popular style than for example an hierarchical approach (Pollitt and Bouckaert 2011; Rhodes 1996). Of course, the only way to determine the value of the model in other governance contexts, is by evaluating it in a more diverse expert group with different cultural backgrounds.

One of the key remarks on the outcomes of the model is that SDI governance seems not very successful as every run always fails after a while. This is indeed

not realistic as in reality actors will adapt to the decreased situation and change the SDI governing strategies and systems (Sjoukema, Bregt, and Crompvoets 2017; Sjoukema, Bregt, and Crompvoets 2020). This adaptive behaviour is indeed absent in the current model as we chose to focus on the effect of governance interaction styles on the SDI governance. By developing a more adaptive future agent-based model where actors themselves choose the type of message, it should be possible to replicate the complex adaptive dynamics of SDI governance.

Another extension to the model could be the addition of more agents. Agent-based modelling is very suitable for larger number of actors with various behaviours. From SDI stakeholder analysis (Coetzee et al. 2018; Coetzee et al. 2019) it appears that in many cases the influential power of an actor can vary heavily. Also the influence of a centralised versus a decentralised network can be examined, as findings from Dessers et al. (2015) indicate that unfragmented processes and centralised coordination lead to a better spatial data performance (Dessers et al. 2015). By incorporating aspects from stakeholder analysis, such as power, proximity and urgency, a more realistic network of SDI actors can be developed (Coetzee et al. 2018; Coetzee et al. 2019). Social network analysis and agent-based models can form a powerful combination (Alam and Geller 2012).

4.6. Conclusion

This research brings together agent-based modelling and SDI governance interactions for the first time. It is thereby a bold and innovative approach, as the complexity of SDI governance emerges from the countless interactions among SDI stakeholders that are difficult to model. However, by simplifying these interactions and developing a generic model, it seemed to be possible to simulate SDI governance in agent-based model which is valued by experts.

As the model allows to influence the local interactions, it becomes possible to play with various governance interaction forms and examine the trade-offs between a hierarchical, network or laissez-faire approach to governance. From the model simulations, it appeared that a network approach was the most effective mode of governance compared to the hierarchical and laissez-faire approach. A continuous budget policy was the most sustainable form, although the pay-per-use budget policy was almost equally successful. The piecemeal

budget policy had the worst performance.

Expert validation revealed that overall the results of the simulation are credible and insightful. The model and its results helped to offer the experts a different perspective to SDI governance as the agent-based model makes SDI governance more tangible and visible. They expressed the need for models like this when discussing new policies, especially currently on the theme of SDI financing. Agent-based models could therefore become an important tool for SDI governors to experiment, learn and discuss how SDI governance interactions evolve and which strategies are effective.

The model in this paper is not the ultimate SDI governance model, but a first stepping stone to develop more advanced agent-based models. By extending this model and developing others, like Lubida et al. (2020) did, SDI governance dynamics can be further examined. Although challenges lie in the validation of the model as it is difficult to empirically validate a governance model, use of agent-based modelling for studying governance proved to be a promising method and a helpful tool for SDI governors for learning and discussion.

Further experimentation and innovation with agent-based modelling in the field of governance is certainly encouraged. By adding more actors, budget policies and social network concepts such as power, distance and trust, the model could gain more depth. And by making the actors behave more adaptive, the model could truly show the dynamics of SDI governance as a complex adaptive system.

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Data availability statement

The overview, design concepts and details (ODD) document is provided as Appendix D. Questions and answers of the expert validation are shown in Appendix C. The Netlogo model is available as supplemental material at <https://doi.org/10.1080/17538947.2020.1868585>.

Chapter 5

The future of INSPIRE: Exploring governance scenarios for the European Spatial Data Infrastructure

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Abstract

The development of a European Spatial Data Infrastructure (SDI) officially started with the enforcement of the INSPIRE Directive in 2007. INSPIRE's implementation phase should be completed by the European Union (EU) member states at the end of 2021. This research evaluates the current European governance of INSPIRE and explores future governance scenarios. First, INSPIRE's governing system is evaluated through an online survey by its main stakeholders. Second, these results are applied in an agent-based model to project future governance scenarios and evaluate alternative governance strategies. The results show that strong aspects of INSPIRE's governing system are the supported vision and its formal structures such as standards, technology and roles and responsibilities. Weak aspects are the access to resources, especially budget and time resources, and data use. The agent-based simulations show that INSPIRE is probably more constrained by its budget resources than its current governance mix, although a combination of adaptive governance and continuous budget proved the most sustainable governance scenario.

Keywords: Spatial Data Infrastructure (SDI); governance; INSPIRE; governing system; agent-based modelling; European Union (EU).

5.1. Introduction

INSPIRE, short for Infrastructure for Spatial Information in the European Community, is a directive of the European Union (EU) to solve problems around the *'exchange, sharing, access and use of interoperable spatial data and spatial data services across the various levels of public authority and across different sectors'* (European Parliament and Council of the European Union 2007, p. 1) among the EU member states. These problems emerged from the notion that policy making on environmental issues becomes hard without integrated spatial information that transcends the local, regional and national boundaries. INSPIRE aims to solve this issue by requiring EU member states to harmonise data on specified themes and provide this data through network services from their national spatial data infrastructures (SDIs) in a standardised manner (European Parliament and Council of the European Union 2007; Cetl et al. 2019; Bartha and Kocsis 2011).

Although the decision to develop INSPIRE was already made in 2001, in 2007 the INSPIRE Directive came into force (Vandenbroucke et al. 2009; Bartha and Kocsis 2011). This Directive requires EU member states to implement the INSPIRE rules on metadata, interoperability, network services, data sharing and coordination into their national regulations (European Parliament and Council of the European Union 2007). From 2007 onwards, multiple milestones were set to implement INSPIRE on 34 spatial data themes in a step-wise manner. At the end of 2021, INSPIRE should be fully implemented (European Commission 2021e, 2021f; Cetl et al. 2019).

INSPIRE implements the SDI concept on a never seen before scale. By requiring all its 27 EU member states to implement the INSPIRE Directive and enabling also non-EU member states to contribute, INSPIRE is *'one of the world's largest coordinated efforts for establishing a Spatial Data Infrastructure'* (Kotsev et al. 2020, p. 1).

INSPIRE brings many positive aspects to the member states. Cromptvoets et al. (2018) show that INSPIRE has impacted the instruments and structures of national SDIs, which strengthens their governance. INSPIRE plays a key role in making public sector geographic information re-usable throughout Europe (Van Loenen and Grothe 2014). Borzacchiello et al. (2018) further add that next to promoting open data, INSPIRE has simplified licensing, harmonised

data, contributed to core reference data, applied the 'once-only' principle and contributed to economic growth by enabling public sector savings while increasing private sector opportunities.

But there is also criticism on INSPIRE. According to Cho & Cromptvoets (2019) many facets of the implementation such as the legal, technical and policy initiatives appear to be top down. Besides INSPIRE, there are multiple other European directives which have similar ambitions on data sharing, which may overload member states and hinder swift implementation (Cho and Cromptvoets 2019). Also, the complexity of the standards, the lack of a user-centric focus and the coordination and support for the Member States from the European Commission could be improved upon (Borzacchiello, Boguslawski, and Pignatelli 2018).

With the official implementation phase coming to an end, INSPIRE is now at a pivotal point to evaluate its current governance. INSPIRE's hierarchical approach, fixed standards and technological requirements helped to guide all member states into the same direction but now may constrain the use and acceptance of INSPIRE. Furthermore, several studies and evaluations have been conducted to evaluate SDI governance of member states (see e.g. Cromptvoets et al. 2018; Vancauwenberghe and van Loenen 2017), but there are currently no independent and critical studies which evaluate INSPIRE's governance at the European level. While it is at this level that important decisions on INSPIRE's structures can be made which impact all stakeholders.

The objective of this research is to evaluate the current state of the European INSPIRE governance and to explore future governance scenarios. This will be done by evaluating the current state of INSPIRE's European governing system. By asking involved stakeholders in the European governance how they experience INSPIRE's current governing system, strong and weak aspects of this system emerge. This evaluation will be used as input for an agent-based model on SDI governance to project how the governance dynamics might evolve from here. By casting multiple governance scenarios, the most sustainable governance approach to the future of INSPIRE can be evaluated.

First, a short overview of the used SDI governance theory and INSPIRE's current European governance is given. Thereafter, the method for evaluating INSPIRE's governance and set up for simulating governance scenarios is discussed.

Thirdly, the results from the evaluating survey and the simulated scenarios are shown. This research ends with a broad discussion on INSPIRE's future and a conclusion with recommendations for INSPIRE's governance.

5.1.1. Spatial Data Infrastructure Governance

Both governance and SDIs are complex subjects. This complexity emerges from the countless local interactions between its stakeholders (Manson, Sun, and Bonsal 2012). In this research, we view the SDI as the system to govern. As SDIs are open systems, which exhibit self-organisation, adaptability and feedback loops, SDIs are also classified as complex adaptive systems (Grus, Crompvoets, and Bregt 2010). This does not mean that SDI governance does not need to be organised. An '*SDI should be able to self-organise and be open to create its own structure (...). However, without any coordinating mechanism it is difficult to successfully establish and manage an SDI*' (Grus, Crompvoets, and Bregt 2010, p. 457).

Like SDIs which are considered as complex open systems, so is governance a complex open process. We define governance as the governing process aimed at solving societal problems or creating opportunities, where multiple actors (both private and public) can influence this process through interactions. Governance is enabled and constrained by structures which give context and establish a normative foundation (Kooiman 2003). This definition and our understanding of governance is derived from the theoretical conceptions of Kooiman (2003), who uses a socio-cybernetic systems perspective on governance (Rhodes 1996). This approach fits well in the context of complex adaptive systems (Duit and Galaz 2008; Kooiman and Bavinck 2013).

The governing process starts with a perceived problem, defined as an 'image'. Instruments are chosen to steer other actors into the desired direction to solve this problem. The choice for an instrument is influenced by multiple factors, like the governing position of an actor and structures such as resources or legislation which enable or constrain the use of certain instruments. This instrument is then put into action, which will affect other actors. They will respond with feedback, which can be used to verify if the problem is solved. This interactive process is enabled and constrained by its structures (Kooiman 2003).

Structures are stable in the short-term and beyond control of a single actor (Giddens 1984; Kooiman 2003). However, through second-order governance

these structures can be changed in the long-term. Kooiman (2003) sees second-order governance (e.g. setting the normative INSPIRE standards) as governance operating on a different level compared to first-order governance, which is aimed at daily problem solving (e.g. implementing the INSPIRE standards). In many cases, structures are able to change when a certain threshold ('tipping point') is reached or an external surprise appears (Duit and Galaz 2008). Then a so-called crucial decision is made to renew the governing system (Klijn and Koppenjan 2016; Sjoukema, Bregt, and Cromptvoets 2020).

Sjoukema et al. (2020) used these theoretical conceptions to develop a governing system framework for SDIs. Based on findings in SDI literature and in practice, important aspects of each part of the SDI governance process (images, instruments, action and structures) are identified (see Figure 5.1). By assessing each aspect whether it is enabling or constraining, the strong and weak points of the governing system of an SDI can become visible (Sjoukema, Bregt, and Cromptvoets 2020).

In this research, we will focus on the European level of INSPIRE's governance and its governing system as at this level INSPIRE's structures are set. This means that we do not focus on how individual EU member states implement INSPIRE, but look at how the overall European governing system of INSPIRE enables its current implementation and its future. The end of INSPIRE's implementation

Figure 5.1. The spatial data infrastructure (SDI) governing system as presented by Sjoukema et al. (2020) consisting of an actor level where interactions, images, instruments and actions happen and a structural level which enables and constrains the actor level. The orange arrow flowing from the left actor to the right actor represents the spatial data flow of an SDI.

phase is a natural moment to evaluate and adapt INSPIRE's governing system through second-order governance before a tipping point event may push INSPIRE into an undesired direction. This research will contribute to this evaluation by using two methods which may be applicable to evaluate governance of other SDIs as well.

5.1.2. Governance of INSPIRE

INSPIRE is designed after the 'SDI hierarchy' pyramid (see Figure 5.2 (Chan and Williamson 1999; Rajabifard and Williamson 2001; Bernard et al. 2005)): *'Inspire shall build upon infrastructures for spatial information established and operated by the Member States'* (Article 2, European Parliament and Council of the European Union 2007). By providing INSPIRE compliant data, metadata and services through these national SDIs, the European INSPIRE geoportal¹ is able to present the decentralised data and services at a central location. Within a member state, these data providing tasks can be delegated to the regional or even local level (Cetl et al. 2019).

The requirements for member states are set through legislation. EU member states had to transpose the INSPIRE Directive and accompanying Implementing Rules into their own legislation (European Commission 2021e). When a member state fails to comply, an infringement procedure can be started by the European

¹ <https://inspire-geoportal.ec.europa.eu/>

Figure 5.2. SDI hierarchy pyramid applied to INSPIRE.
Adapted from Chan & Williamson (1999).

Commission. Through this legal procedure, compliance can be enforced through court procedures and financial penalties (European Commission 2021d). At the beginning of INSPIRE, against almost every member state an infringement procedure was started as they failed to transpose the Directive on time (Cho and Crompvoets 2019).

This does not mean INSPIRE is governed solely top down through enforcement. All EU member states are represented in the Maintenance and Implementation Group (MIG), together with EU candidate states, European Free Trade Association (EFTA) members and the INSPIRE coordination team. This INSPIRE coordination team consists of the EU bodies: Directorate-General (DG) Environment, Joint Research Centre (JRC) and the European Environmental Agency (EEA). There is a technical sub-group of the MIG, called the MIG-T, for the technical aspects of INSPIRE such as its technical implementation and standards. Through participatory processes the legally binding Implementing Rules on metadata, data specifications, network services and more, and the non-legally binding technical guidance documents were developed (European Commission 2021e, 2021h).

5.2. Method

In order to evaluate the current European governance of INSPIRE and explore future scenarios, we used a two-step method. First, we evaluated the perceived governance state of INSPIRE by its stakeholders through an online survey. Second, output of the survey was used as baseline scenario to simulate INSPIRE's governance with the help of an agent-based model developed by Sjoukema et al. (2021).

5.2.1. Survey on INSPIRE's governance

Objectively evaluating governance is difficult due to multiple reasons. First, within governance the perception of its actors ('image') determines whether a situation is problematic or not (Klijn and Koppenjan 2016). Second, governance theories set a normative foundation which also changes over time ('third-order governance' (Kooiman 2003)). For example, from the late 1970s to the late 1990s there was a high focus on running governments as businesses in order to improve efficiency, which later changed into the current more inclusive focus on governance (Pollitt and Bouckaert 2011). Third, like other complex adaptive systems, SDIs are path-dependent and open systems (Grus, Crompvoets, and

Bregt 2010), which makes their governance highly case and context specific.

Therefore, we chose to measure in this research the perceived governance state of INSPIRE's governing system by asking involved actors how they experience its governance. For the operationalisation of governance aspects, we used the governing system framework for SDIs as developed by Sjoukema et al. (2020; see section 5.1.1) and transformed this framework into an online survey. By asking questions on each aspect as indicated in Figure 5.1, stakeholders involved in the European governance of INSPIRE could indicate what their perception of the governance of INSPIRE is. As most questions were Likert type questions on a five point scale, we used descriptive statistics to evaluate the results on each governing aspect. Then, an overall view on the weak and strong points of the governing system of INSPIRE emerges.

A few modifications were made in the governing system framework to improve its suitability in an online survey and to use the results as input for the agent-based model (see section 5.2.3). These modifications were mainly made in the instruments category. As it is difficult to evaluate the type of instruments used, we asked respondents which type of governance they think is the most dominant and if they could indicate how these governance types are distributed. The governance types which could be chosen are hierarchical governance (top down governance, e.g. governing by legal obligations and requirements), network governance (horizontal governance, e.g. collaboration in working groups with a mix of stakeholders, exchanging knowledge and ideas) and laissez-faire governance (central governance is absent, which gives room for e.g. self-organised public and private bottom-up initiatives). Furthermore, we split some aspects into multiple statements, such as the questions on data quality and availability, as these aspects can be broadly interpreted.

5.2.2. Survey dissemination

The survey was distributed among all MIG and MIG-T members. Also members from the European Commission and other involved European agencies were invited to participate. The reason to only distribute the survey among members of the MIG is that they are more involved in the European governance of INSPIRE and, therefore, also more knowledgeable about the subject. They have, for example, better knowledge on how collaborative decisions are made and how input from members is handled. Furthermore, with this group the survey reaches

all member states evenly and all persons are familiar with the English language so no translations of the survey were needed.

Of course, there is also a downside by narrowing the research population to this group. Stakeholders in this position may have a different perspective on INSPIRE's governance because of their involvement than stakeholders and users on the operational side who might experience the governance of INSPIRE differently. However, distributing the survey among all INSPIRE stakeholders evenly would be difficult as INSPIRE's users are largely unknown and most stakeholders are further positioned from the decision making processes, which makes them less able to rate every governance aspect. Therefore, the MIG group seems to be ideal to evaluate the European governance of INSPIRE, but we have to be aware that the perspective of other involved stakeholders on the governance of INSPIRE is missing which may influence the results.

The survey was held from 9th of November till the 26th in 2020. The survey was distributed to 64 MIG members, 39 MIG-T members and 26 EU stakeholders through e-mail. Six e-mail addresses were not working or blocked the e-mail, which brings the total research population to 123. The survey was provided through an anonymous link, which means we could not check who responded and if the survey was further spread which was not encouraged or discouraged.

5.2.3. Agent-based model for SDI governance

Governance is not a static but a dynamic process. As we do not only want to evaluate INSPIRE's current governing system, but also cast projections and stimulate discussion about the future governance of INSPIRE, we used the agent-based model on SDI governance as developed by Sjoukema et al. (2021). Agent-based modelling is a method to simulate complex adaptive systems. By programming local interactions it becomes possible to reproduce complex emergent macro level behaviour. Even simple models help to improve our understanding of the dynamic real-world phenomena they simulate (Bonabeau 2002; Manson, Sun, and Bonsal 2012).

Sjoukema et al. (2021) developed a generic model to study SDI governance dynamics over time, which is validated by experts through face-validation. With this model it is possible to simulate SDI governance interactions and modify parameters to project different scenarios. As most input values for the model are measured by the survey, it becomes possible to simulate multiple governance

strategies and cast scenarios for INSPIRE. The following section will explain shortly the model working and the modifications we made to simulate INSPIRE. For a full understanding of the model we refer to Sjoukema et al. (2021; chapter 4) and the accompanied Overview, Design and Details (ODD (Grimm et al. 2010)) protocol as Appendix D.

The model works as follow: there are four actors (SDI executive, SDI data provider, SDI platform provider and SDI user) representing a group of SDI stakeholders with a specific role. Each actor has a satisfaction attribute on a 0 till 10 scale indicating their current satisfaction with the SDI and its governance. They can interact by sending three types of messages to another actor: hierarchy messages, representing hierarchical governance, network messages, representing network governance and no messages, representing laissez-faire governance. The choice for these messages depends on their role and the chances on a certain message type, defined as input setting on a 0 to 100% scale. Based on the ideas of Dietz et al. (2003) on adaptive governance, actors prefer a governance mix: when the received message types are alternating, the satisfaction of the receiver is positively influenced and they provide positive feedback to the sender of the message. However, when they get too many messages of the same type in a row, their satisfaction will drop and they provide negative feedback. A single hierarchical message representing a 'hard' instrument boosts the satisfaction more than a 'soft' network message. However, the receiver's tolerance for multiple hierarchical messages in a row is lower compared to the network messages. The no messages do not have a direct positive effect, but do count in the alternation of messages (Sjoukema et al. 2021).

Meanwhile, the SDI data provider and platform provider have the job to provide high quality data to the SDI user. The satisfaction of the data and platform provider does not only represent how they perceive the SDI and its governance, but also influences the data quality which is also represented on a 0 till 10 scale. Furthermore, they need to spend maintenance costs to keep this data quality high (data quality is higher than 5) and invest extra budget if they receive negative feedback on the quality from the user (data quality is lower than 5). The resources for the maintenance costs may be supplemented (partially) by other actors, depending on the selected budget allocation policy (Sjoukema et al. 2021).

Translated to the context of INSPIRE, the role of SDI executive corresponds to the European Commission where especially the INSPIRE coordination team consisting of DG Environment, JRC and EEA play important roles. The role of SDI data provider corresponds with the EU member states. Responsibility for the SDI platform lies partly by the member states and partly by the European Commission. INSPIRE's users can be anyone, both on the European, national, regional or local level.

Some results from the survey are used as input settings for the model. Within the model it is possible to adjust settings on the satisfaction of stakeholders, their budget, the type of governance interactions and the susceptibility of actors to feedback. As these aspects are covered by questions in the survey, we can set these parameters according to the results as starting point for the simulations.

The model of Sjoukema et al. (2021) allows to differentiate in budget policies. However, in all original budget policies of this model, budget flows from one actor (the SDI executive or SDI user) to the actors who are bearing the costs for providing the data (SDI data provider) and hosting the SDI platform (SDI platform provider). In INSPIRE there are no direct funds from the user or executive: EU member states have to cover their own costs they make by providing INSPIRE datasets and technical services. To simulate such a policy, we created a new budget policy in the model called 'INSPIRE financing'.

In this policy, the data and platform provider pay the maintenance costs until they cannot afford this anymore. If the data quality is still good according to the data user (> 5 on a 0 to 10 scale), this situation remains. However, when they get negative feedback from the user, they will obtain an extra budget and invest extra to improve the data quality, until the previous situation occurs again. Of course, this is a simplification of the reality where every member state has a different approach to financing INSPIRE. However, this approach simulates the balance member states may seek between conforming to the INSPIRE regulations and spending as little as possible, as multiple countries are critical on the costs for especially data harmonisation compared to the benefits (e.g. Austria (Bundesministerium für Landwirtschaft 2020), Belgium (Agentschap voor Geografische Informatie Vlaanderen 2020) and the Netherlands (Hulsker et al. 2016)).

To get a full understanding of this model and the technical modifications we

made to the model of Sjoukema et al. (2021), an updated version of their Overview, Design concepts and Details (ODD (Grimm et al. 2010)) document is provided as Appendix D.

5.2.4. Scenarios for simulating INSPIRE's governance

With the help of the agent-based model we can simulate SDI governance dynamics and ask 'what if' questions. The simulation results serve as learning purpose to understand from what kind of governance interventions INSPIRE may benefit. We set up four scenarios to see what could happen to INSPIRE's governance: a baseline scenario, a continuous budget scenario, an adaptive scenario and a combined scenario. The following section discusses shortly each scenario:

5.2.4.1. Baseline scenario

The baseline scenario acts as reference scenario. In this scenario we use the results of the survey as input settings and keep these settings stable. The budget policy is set to the newly developed 'INSPIRE financing' as explained in section 5.2.3. In this way, we explore what happens if INSPIRE's governance continues on the current foot.

5.2.4.2. Adaptive scenario

However, in most cases, SDI governance adapts (Sjoukema, Bregt, and Crompvoets 2017; Sjoukema, Bregt, and Crompvoets 2020). Therefore, the adaptive scenario explores how INSPIRE's governance would look like if it would be more adaptive compared to the baseline scenario. The same input settings and budget policy as the baseline scenario are used. However, after 15 time steps the average satisfaction of the actors is evaluated. If it is below 7.5 (on a 0 till 10 scale), the governance mix is automatically adjusted based on the distribution of sent messages: chances on a certain message type are set higher for the least sent messages while settings for the most sent messages are set lower.

5.2.4.3. Continuous budget scenario

In the continuous budget scenario we explore how the governance dynamics are influenced when budget for the maintenance costs of the SDI is continuously provided by the SDI executive. The governance mix is kept stable at the input settings, like in the baseline scenario.

5.2.4.4. *Adaptive + continuous budget scenario*

This scenario combines the settings of the previous adaptive and continuous budget scenario. Budget is continuously provided and after 15 time steps, the satisfaction of the actors is evaluated in order to adjust the governance mix.

5.2.5. **Simulation outputs**

Like real world governance, a simulation run with the agent-based SDI governance model is always unique. Depending on factors such as chance and coincidence, a model run with the same setting can be either highly successful or a failure. To diminish this stochastic effect, we ran each scenario 1000 times, so we can distinguish reliable trends from each scenario. The simulation stops automatically when the average satisfaction of actors is 1 or less. Success of a scenario is measured by its average life span, which means counting the amount of time steps until it stops. A second measure for evaluating the success of a scenario is the success/failure ratio. This ratio is calculated by counting the amount of runs that run for 70 time steps or more, and divide these by the total amount of runs. The time steps resemble the development of the simulation over time and its relation with real time is not specific (Sjoukema et al. 2021).

5.3. **Results**

This section describes the results from the survey and agent-based simulations. First the survey response is discussed. Thereafter, an evaluation of INSPIRE's governance is given, by putting the survey results within the governing system framework as shown in Figure 5.1. The third part shows the results of the agent-based modelling simulations.

5.3.1 **Survey response**

Table 5.1 shows the survey response. From almost every EU member state at least one response was registered. Only no stakeholders from Ireland, Lithuania and Poland responded. From the Czech Republic more results (13) came in than the actual research population (4). Probably because the survey was shared broader. To control if this large response did not skew the results too much, we tested if the responses from the Czech respondents and non-Czech respondents differed significantly with a Mann-Witney U test (Lewis-Beck, Bryman, and Futing Liao 2004).

In total 42 questions were tested, which resulted in only 3 questions with a

Table 5.1. Survey response compared to original research population.

	Research population	Response	Response rate
EU Member states	86	48 ¹	56%
Non-member states	14	3	21%
EU level	23	4	17%
Total	123	55	45%

¹ More responses (13) came from the Czech Republic compared to the original Czech research population (4), boosting the response rate for EU member states.

significant difference ($p \leq 0.05$): organisational culture, data provision and data use. These questions were rated more positively by the Czech respondents. This led to small differences of +0.1 or 0.2 for these questions when we compared the average response of the whole population to the average response of the population with the Czech response excluded. Of course, totally excluding this group would not give more accurate results as the original Czech research population existed of 4 respondents. Given this reason, the low rate of statistical differences and the minor influences on the resulting averages, we decided to use all responses for our analysis.

Response from the non-member states and the EU level was much lower compared to the EU member states. Especially the relatively low response from the EU level is remarkable as multiple EU organisations are involved in INSPIRE's governance as coordinator or as main user.

Most respondents have a long involvement in INSPIRE (see Figure 5.3). The majority (80.0%) has an involvement for over 5 years or longer. When looking at SDI roles, most respondents (87.3%) classify themselves as SDI executives (see Figure 5.4). This means they have coordinating tasks. As it was possible to select multiple roles, many also responded to be a data provider (58.2%) and/or a platform provider (47.3%), which means they are busy with delivering INSPIRE data and/or hosting INSPIRE webservices. These outcomes are not surprising, given the fact that MIG members are mostly the organisational or technical INSPIRE coordinators in their country. The role of researcher or data user was less frequently mentioned. Given the research population this is also not surprising, although it does indicate a relative low share of involvement of INSPIRE's users in its core governance.

Figure 5.3. Pie graph showing the years of involvement in INSPIRE of survey respondents.

Figure 5.4. Graph showing respondent's roles in INSPIRE. Multiple answers were possible.

5.3.2 Evaluating INSPIRE's current governance

To discover the strong and weak aspects of INSPIRE's governance, we calculated averages, medians and modes on each aspect in the governing system framework. Figure 5.5 shows the averages and their place in the governing system framework. These scores are based on the Likert type statements from the survey on a 1 till 5 range: 1 means very negative, 3 is neutral and 5 is very positive. Instruments are the only aspects which were not classified on a Likert scale, but as a percentage to get a feeling of the distribution of instruments. The results to each survey question and other statistics can be found as supplemental information.

Overall, the governing system of INSPIRE is rated positively as most aspects score above 3. When looking at the image category a paradox emerges: the goal and vision of INSPIRE was highly rated and the statement '*I support the goal and vision of INSPIRE*' scored the most positive of all questions. However, a statement about alignment of opinions among its stakeholders scored much worse. A possible explanation lies in the fact that the bigger vision and goals of INSPIRE could be clear and supported, but the way to get there can be a point of discussion. From a governance perspective, a diversity of opinions does not

Figure 5.5. This figure presents in the SDI governing system framework of Sjoukema et al. (2020) the average scores from the survey results on each governing aspect. Each aspect is scored on a 1 till 5 range: 1 means very negative, 3 is neutral and 5 is very positive. Aspects scoring less than a 3 are underlined.

necessarily have to be a bad thing. *'People bring varying perspectives, interests, and fundamental philosophies to problems (...), their conflicts, if they do not escalate to the point of dysfunction, can spark learning and change'* (Dietz, Ostrom, and Stern 2003, p. 1909). A clear, common and supported vision helps to steer the SDI in the desired direction (Kok and van Loenen 2005).

When looking at the instruments category it is clear that INSPIRE is largely hierarchical governed. This is not surprising as its implementation strategy is largely based on legal regulations which member states have to follow. From the additional comments left by respondents, this is on the one hand positive: *'I am an advocate of (...) the centralized way of building INSPIRE. Otherwise we do not have any standards.'* Another adds it should be even stricter: *'By being stricter, (...) the results would have been better for use much earlier. The easiest example is an obligation to provide metadata in English.'* However, it is also negatively reviewed: *'The strong binding to legislative aspects does not allow the suitable flexibility for technical implementation that would reach to better operable solutions.'* Or as one respondent summarises: *'The legal obligation has been the key motor for implementation and the biggest constraint.'*

5 All action aspects are positively reviewed, which enables the implementation of INSPIRE. Although one respondent adds that although leadership is strong, users are largely uninvolved and INSPIRE would need to focus on the user more. This data push approach is also apparent from the evaluation on INSPIRE's data: the availability and provision are positively rated, but the data content (e.g. its usefulness) and its use are negatively evaluated. This is currently a main challenge for INSPIRE.

At the structural level we can see that most formal structures such as roles & responsibilities, law, technology and standards are seen as enablers. Many resources are negatively reviewed, such as the access to political capital, time and especially budget resources. In fact, the statement on budget resources was the lowest scoring statement. Again, this is explainable as the EU does not provide any budget to member states to provide harmonised data and services and, in many cases, member states do not directly benefit from the INSPIRE obligations. The informal structures, such as trust, support and culture balance around a neutral score: they are not very enabling, but also not constraining.

5.3.3 Exploring future scenarios for INSPIRE’s governance

Table 5.2 shows how the survey results are used as input setting for running the agent-based model simulations. Some results had to be converted in order to fit the model inputs. These settings are then used to simulate the four scenarios (baseline scenario, adaptive scenario, continuous budget scenario and adaptive + continuous budget scenario) as discussed in section 5.2.4.

Table 5.2. This table shows how the survey results are converted in input settings for the agent-based model. The settings for the susceptibility to feedback and budget resources had to be converted in order to fit the model inputs.

Parameter	Survey result	Model input setting
Satisfaction of INSPIRE stakeholders ¹	6.5/10	6.5/10
Susceptibility to feedback	3.5/5	70%
Budget resources	2.4/5	5/10
Hierarchy messages	52%	52%
Network messages	40%	40%
No messages (laissez-faire)	18%	18%

¹ Please note that we do not differentiate the satisfaction per actor (SDI executive, SDI data provider, SDI platform provider and SDI users) in the model as due to the multi-level nature of INSPIRE, respondents have multiple roles as indicated by Figure 5.4.

Figure 5.6 and 5.7 show the simulation results. Figure 5.6 shows the average life span per scenario, which is the average amount of time steps a simulation took before it failed. Figure 5.7 shows the success/failure ratio for each scenario. Compared to the other scenarios, the baseline scenario performs the worst. Interestingly, the adaptive scenario performs less than the continuous budget scenario. An explanation could be that, currently, INSPIRE’s financing is constraining its governance dynamics more than the current governance mix. This seems to correspond with the survey results (Figure 5.5) as budget resources were the lowest scoring aspect. However, by combining the adaptive scenario and continuous budget scenario, the simulation performs the best. The following section discusses these results further and provide recommendations for INSPIRE’s governance.

5.4. Discussion

This research shows in a clear and visual way the current state of INSPIRE’s European governance and projects the possible effects of governance

Figure 5.6. Average life span in time steps per simulated scenario.

Figure 5.7. Percentage of runs that are classified as successful compared to the other runs. Success is defined as running for 70 time steps or longer.

interventions. The two-step research method with a survey and agent-based simulations were used for evaluating INSPIRE’s governance but can be applied to study the governance of other SDIs. Compared to traditional case studies on SDI governance, this approach makes the subject more tangible and concrete.

Evaluating governance is a difficult task, but the survey proved to be an efficient way of gaining more insights in the governing system of an SDI. With some minor modifications, this survey can be broader applied by SDI governors and researchers to evaluate the perceived governance state of other SDIs at

different levels. By presenting the results in the governing system framework, a concise overview of the governing system appears. Furthermore, by using the survey results as input data for the agent-based model, potential effects of governance interventions can be explored.

However, these methods also have their limitations. The survey was now only sent to stakeholders with a high involvement in INSPIRE's European governance. The perspective from users and stakeholders on the operational side of INSPIRE's European governance is missing. Although these groups may have less experience with the decision-making processes of INSPIRE, they are confronted with the decisions and physical appearances of the SDI such as the standards and data. Therefore, for the evaluation of the governing system of an SDI it is a valid choice to ask only the highly involved stakeholders. However, asking a broader group of stakeholders will be of added value to better measure stakeholder's sentiment, and therefore, the satisfaction surrounding an SDI and its governance.

Another limitation lies in the richness of the agent-based model to simulate SDI governance. As some modifications were necessary to adjust the agent-based model to the INSPIRE circumstances, further development of this model is advisable to make it better applicable and more refined for other SDIs in different contexts. For example, the model could be further extended to incorporate the SDI hierarchy aspects INSPIRE deals with.

Nevertheless, this innovative methodological approach proved to be valuable to the complex subject of SDI governance. To our surprise the adaptive scenario performed less compared to the continuous budget scenario. We expected that by making the governance mix adaptive, the governance would behave more like a complex adaptive system and become more sustainable than when the governance mix is fixed. However, the simulations inform us that without structures which enable the governance, the adaptive effect is small. This may not be very surprising as both the results from the survey and simulations show that budget resources are the most constraining factor to INSPIRE's current governance.

The continuous budget scenario implies that the central actor of the SDI recovers the main costs for providing and hosting the data. One may argue that centrally and continuously financing INSPIRE is unnecessary, as EU budget comes from

its member states and thus from their own pockets. However, allocating budget to member states can raise their motivation to contribute to INSPIRE and with financial incentives, innovation and self-organisation around INSPIRE can be stimulated. A downside could be that member states' incentive to operate cost-effectively in their contribution to INSPIRE may be less. However, one may wonder if that is a negative outcome as member states now may try to do as little as possible for INSPIRE in order to adhere to the legal requirements, while keeping its own costs low. Such attitude will hinder INSPIRE to reach its full societal value.

On the other hand, in general, extrinsic motivations such as legal obligations or financial incentives may be weaker motivators compared to intrinsic motivations: motivations that come from within (Bénabou and Tirole 2003). It is important that INSPIRE stakeholders have the feeling that their efforts are meaningful, which is highly related to its use. Use may be one of the most important factors to measure SDI success (Welle Donker and van Loenen 2017), but the survey results indicate a relatively low score on this aspect.

SDI use may follow an S-shaped diffusion curve, with a few early adopters at the start and an increasing growth after the SDI is valued and trusted broader (Rajabifard, Feeney, and Williamson 2002). This growth period may already have been started as a Dutch vision document on INSPIRE notices: *'What stands out is the huge increase in the number of [INSPIRE service] hits from 2015 onward, (...) which somewhat undermines the overall impression that INSPIRE is not being used'* (Van Arragon et al. 2019, p. 11). To counter this negative image, it is important that INSPIRE's use is monitored and communicated. When use is perceived low, stakeholders will question if it was worth the costs. To help align images on this aspect, critical cost-benefit analyses may help to prove its value (Griffin, Coote, and Cromptvoets 2019). When INSPIRE's use and value is visible and communicated enthusiastically, it can motivate both INSPIRE's data providers and potential INSPIRE users. Shortly put: INSPIRE could inspire more.

Recently, the INSPIRE work programme 2021-24 was launched (European Commission 2021g). This programme focusses on five objectives which should provide a future vision, prioritise datasets and themes, diminish the current heterogeneity of data, simplify technical requirements and transform INSPIRE from a legal framework towards a 'digital ecosystem for environment and sustainability' (European Commission 2021g). Furthermore, these goals are

related to the European Green Deal (European Commission 2021b) and the EU Common Data space.

Multiple governance issues found by this research are addressed by these new objectives. By appending INSPIRE to the large strategic programmes of the EU such as the Green Deal (European Commission 2021b) and Digital Europe Programme (European Commission 2021a), access to political capital can be enhanced. By diminishing the heterogeneity of the data and focussing on the ‘crown jewels’ (European Commission 2021g), the usefulness and thereby the use of data will be improved. Simplifying the technical requirements may both reduce costs for member states as well as for users. By striving for an ‘agile approach and sandboxing’ and the creation of ‘communities’ (European Commission 2021g), the governance mix changes with more network and self-organisation, which will increase the flexibility and adaptiveness.

However, this will probably not solve all identified issues by this research. Although the working programme has an action for a ‘need-driven data prioritisation’ and users are mentioned a few times as relevant stakeholders (European Commission 2021g), most INSPIRE users are not yet structurally embedded in its governance. This provides a risk that these need-driven priorities not necessarily correspond with the broader user needs of INSPIRE’s stakeholders. Next to the importance of a vivid user community, a strategic user group which advises the MIG may be essential to structurally embed the voice of users in INSPIRE. Furthermore, the programme does not address the budget issue, which may constrain the implementation of these changes and the desired flexibility.

5.5. Conclusion

The objective of this research was to evaluate the current European governance of INSPIRE and to explore future governance scenarios. With the help of the governing system framework, we evaluated INSPIRE’s governing system. Based on this research, strong aspects of INSPIRE’s governing system are in the supported vision and formal structures such as standards, technology and roles and responsibilities. Weaker aspects are in the access to resources, especially budget and time resources, and data use. The agent-based simulations showed that INSPIRE is probably more constrained by its weak access to budget resources than its current predominantly hierarchical governance mix. However,

by combining a continuous budget approach with a more flexible and adaptive approach to its governance, this might enable INSPIRE's sustainability for the future.

INSPIRE helped to forge a common base of policies, standards and technology among the EU member states. For the future of INSPIRE it is key to consider its strategies for the next phase. In general, we recommend that INSPIRE focusses now on how to increase its value. A more flexible way of governance, with especially more room for network and self-organisation and a better inclusion of users, can help to shift this focus. The new INSPIRE work programme takes steps in this direction, although it does not address the identified budget issue and embed users structurally in its governance. However, by appending to the large strategic programmes of the EU such as the Green Deal, INSPIRE can prove its value and may increase its access to political and budget resources.

This research used and refined two previously developed methods (Sjoukema, Bregt, and Cromptvoets 2020; Sjoukema et al. 2021) to evaluate SDI governance and applied it to INSPIRE. These methods help to gain a better insight in the European governance of INSPIRE, although limitations are in the research population and the simplicity of the agent-based model compared to the real-world governance complexities. Future research could focus on making agent-based models more refined and applicable in different SDI governance contexts. For INSPIRE, especially more research on its users and how to incorporate them in its governance is recommended.

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Supporting information

The survey questions and results are available as supporting information to the article. Furthermore, a technical description of the agent-based model and the modifications according to the overview, design concepts and details protocol of Grimm et al. (2010) is added as Appendix D.

Chapter 6

Synthesis

6.1. Main findings

In chapter 1, the concept of SDIs and governance were explained. Both are complex and dynamic subjects that evolve and adapt over time. In order to get a better understanding of this behaviour and provide guidance for the future, the main objective of this research was defined as *'to analyse SDI governance dynamics and to develop tools in order to gain insights in current SDI governance and their possible future.'* This objective was divided into four sub-goals:

1. Analyse the adaptive behaviour of SDI governance
2. Develop a framework to evaluate SDI governance dynamics
3. Develop an agent-based model to simulate and examine SDI governance dynamics
4. Evaluate the current governance state of an SDI and explore future governance scenarios

This chapter will first conclude the results in achieving these objectives. Followed by a section which will reflect on this research and discusses its role in current scientific debates on SDIs and their governance. Thereafter, insights and recommendations for SDI governance in practice are presented. At last, future research challenges for gaining an even better understanding of SDI governances are proposed.

6.1.1. Analyse the adaptive behaviour of SDI governance

Chapter 2 and 3 studied the adaptive behaviour of SDI governance by case studies. In all four studied cases (Key Registry Large-scale Topography (BGT), Large-Scale Reference Map (GRB), Risk Map and New Map of the Netherlands) we found that SDI governance trajectories changed considerably over time. In fact, no studied SDI case appeared to be able to keep its governance stable over a longer time period, because either the SDI was not meeting their goals, did not satisfy all its stakeholders, did not fit the new visions and ideas, or its structures such as its laws or standards became too constraining. Rigorous shifts in the governing system were noted in all cases.

Especially noticeable in the evolution of the studied SDIs is the fact that they appear to emerge from self-organised networks and then strived for more central and hierarchical governance. This trajectory does not have to be linearly as especially the Key Registry Large-Scale Topography (BGT) proves. The case of the New Map of the Netherlands shows why it is important for an SDI to

be institutionally embedded as this was the only studied SDI which was not institutionally embedded and (temporarily) ceased to exist.

While central and hierarchical structures can act as important lifelines for SDIs, perhaps the self-organising ability of its stakeholders is a more important feature for the adaptive capacity of SDIs. At the early 90s, the predecessor of the BGT was stripped away from its legal structure, but through networks and self-organisation this actually marked a very productive period for the data completion. Also, the New Maps of the Netherlands re-emerged through an initiative of volunteers.

It indicates the importance of having a mix of self-organising, network and hierarchical governance for the adaptiveness of SDI governance. It is also important that the structures of the governing system are regularly reviewed to determine if they are still enabling the governance or have become constraining. We witness that most studied cases only change their system radically after it slipped into a crisis, which was either due internal events, external events or a combination. To conclude, SDI governance is already adaptive, but SDI governance in general can anticipate better on its dynamics in order to increase the adaptive capacity and prevent governance crises.

6.1.2. Develop a framework to evaluate SDI governance dynamics

Chapter 3 further presented a framework to evaluate the changes in the governing system of SDIs adapted from the theoretical conceptions of Kooiman (2003). The governing system framework contains four main elements: images, instruments, action and structures. The first three form the actor level of governance, where the daily governance interactions take place. The structures such as institutions and resources reside at the structural level, which enables and constrains this actor level. Furthermore, SDI performance qualities are added to the framework to understand the relation between the governing system and the performance of the SDI. Also, interactions were added to understand the formality of the used interactions between actors.

By analysing SDI governance with the help of this framework, strong and weak aspects of the governing system of an SDI become visible. By using the radical changes in SDI governance as a reference point in time, the so-called crucial decisions, we were able to compare the relative difference in the governing

system of an SDI. Therefore, it is a promising tool to analyse and understand SDI governance and their dynamics for both science and practice.

In chapter 5 this framework was applied with a few minor modifications to analyse the governing system of INSPIRE, the European spatial data infrastructure. In contrast to the qualitative analysis in chapter 3, in this analysis surveys were used to generate the data for analysis. This proved to be a quick and efficient way of gathering the data. By doing this on regular intervals (e.g. yearly) more insights can be gathered on the shifts in governing systems.

6.1.3. Develop an agent-based model to simulate and examine SDI governance dynamics

Chapter 4 presented a novel approach to SDI governance by using agent-based modelling to simulate SDI governance interactions. Although SDI governance is a highly complex subject, by simplification of its interactions, it became possible to simulate SDI governance. From expert validation it appeared that the results of the simulation are credible and yield more insights in SDI governance. Overall, the model was valued positively by the experts.

With the help of agent-based simulations, SDI governance dynamics become much more tangible and visible compared to an average policy document. Furthermore, it becomes possible to ‘play’ with the various governance interactions and trade-offs. From this model, we learned that a network approach is likely the most sustainable governance approach, compared to a hierarchical or laissez-faire approach. On the structural level, continuous funding proved to be the most successful although it was closely followed by a pay-per-use approach.

This model is a first attempt to simulate the complexities of SDI governance and should not be the last. In chapter 5 already a few extensions were made to run simulations on the governance of INSPIRE. For both SDI scientists and practitioners, agent-based modelling is a promising tool for gaining more insights and to learn and discuss SDI governance.

6.1.4. Evaluate the current governance state of an SDI and explore future governance scenarios

Both the developed governing system framework and the agent-based model were applied in practice on INSPIRE in chapter 5. INSPIRE is an initiative to

develop an 'Infrastructure for Spatial Information in the European Community'. Currently, the implementation phase of INSPIRE should be almost ended which makes this a pivotal point to think of its future. By using surveys among its main stakeholders to collect information about the current European governing system, an evaluation of the strong and weak aspects of INSPIRE's governance became visible. Strong aspects of this system are in its formal structures (e.g. standards, technology and roles and responsibilities), while the weaker aspects are in the data use and access to resources. Especially time and budget resources were seen as constraining.

By using the agent-based model from chapter 4 with some small modifications and extensions to make the simulations more adaptive and adhere to the budget policy of INSPIRE, we were able to explore future governance scenarios of INSPIRE. Results from the survey were used as input settings and a baseline scenario was simulated. Next to this scenario, simulations were run to find out how the success of INSPIRE is increased by using a continuously provided budget and a less rigid, more adaptive approach to INSPIRE. Especially a combination of these changes proved to be the most successful. By making the governance of INSPIRE on the one hand less rigid, with a better inclusion of users and more room for network and self-organised governance, and on the other hand enable member states more by providing budget and putting INSPIRE on the political agenda, INSPIRE's future may look bright.

6.2. Overall reflection

This research analysed the complex and dynamic behaviour of SDI governance. Based on the studied cases, it is clear that there is no golden recipe for SDI governance. Even if the results are very similar as in the case of the large-scale base maps of chapter 2, governance trajectories of SDIs can be very different. SDIs truly behave like complex adaptive systems. They are path-dependent, unpredictable, sensitive to external influences and show a high degree of self-organisation. Therefore, this research focussed not on finding a golden recipe, but on a better understanding of how SDI governance adapts and on the development of tools to better understand governance dynamics of SDIs.

This section will reflect on the found results and used methods. First, the consequences of an adaptive perspective on SDI governance are discussed. Thereafter, the implications and limitations of the governing system framework

and agent-based model are evaluated subsequently. Finally, the future of SDIs and their governance is discussed.

6.2.1. Adaptive governance and SDIs

This research used longitudinal research for studying SDI governance dynamics in chapter 2 and 3. Studying SDIs on a time scale of twenty years or longer was very insightful for understanding these dynamics. However, it also may give a feeling of disillusionment as we found out it really took a long time from the first idea to successful SDI implementation and somehow, SDI governance always seems to slip down into a crisis. Furthermore, not only SDIs and their governance showed dynamics, also ideas on governance changed over the years, which influenced the goals and development of SDIs considerably.

External events, such as the financial crisis of 2007 - 2008 and the COVID-19 pandemic have showed us how unpredictable the world can be. Such external events can affect the trajectory of an SDI considerably, both positively (e.g. the Risk Map emerged from an external crisis which showed a lack of information on hazardous substances and their location) and negatively (e.g. the New Map of the Netherlands stopped because of budget cuts due to the financial crisis and accompanying housing crisis). But also a change in governing paradigm, such as the open government, are highly influential on the development and trajectories of SDIs.

6 These lessons on governance dynamics and complexity make it a difficult process to grasp. Governance is not a linear process and moves at different speeds on different levels in different contexts. When this research studied even more SDIs in different contexts probably completely different SDI governance trajectories would be found. And, when this research was conducted twenty years in the past or twenty years in the future probably a different perspective on SDI governance would be applied.

However, we do not have to be disillusioned about these complexities and dynamics. In chapter 2 we saw that these SDIs become more and more institutionalised, which give them a more mature governing system and make them more robust for external surprises. In chapter 3 we saw that with contemporary technologies, establishing an SDI appears to be much easier than in the past. The New Map of the Netherlands showed it is challenging but possible to self-organise an SDI based on volunteerism if the institutional context

is largely absent. Finally, we also see in the Belgian and Dutch contexts that SDI governance crises are not a prerequisite for change. For example, we see in Flanders that SDI governance becomes more and more adopted in broader e-government strategies, without an urgent crisis to solve (see chapter 2). In the Netherlands, there are developments to better integrate the geographical key registries even though they are highly used (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties 2021).

These developments indicate that SDI governance can also adapt incrementally. It may even be that SDIs are considered as complex adaptive systems, because of their adaptive governance processes at work. To prevent crisis situations, it is important to enable and guide this adaptive behaviour. By letting feedback flow so the images are aligned and the SDI is supported by its stakeholders, the SDI can be navigated into the desired direction. Structures and resources may anchor and enable this process. By regularly measuring the governing system of an SDI, early cracks in this system may become apparent.

6.2.2. SDI governing system framework

Chapter 3 presented this governing system framework, based on literature on SDI governance and governance in general plus findings in practice. Although qualitative research such as document analysis and interviews proved to be helpful to establish and fill this system for the first time, quantitative research such as the survey used in chapter 5 makes the use of this framework much easier. Potentially, the governing system framework could also be very useful when applied in workshops, panel discussions or board meetings to analyse the strengths and weaknesses in the governing system of any SDI.

The governing system framework was developed as SDI practitioners made clear that they needed tools and guidance to better govern SDIs. But despite the popularity of governance research, there were few scientists who dared to operationalise this complex process. One of the exceptions was Kooiman (2003), although there was still a gap between his theoretical conceptions and the operationalisation of governance.

Operationalising governance is also not without risk, as governance theories set a normative foundation (Kooiman 2003). Governance science influences governance practice and vice versa. This is for example noticeable in the rise of the market-driven reform of new public management in the 1980s. Pollitt and

Bouckaert (2011) note that together with this rise, there was also political shift and *'the selling of management ideas was one of the growth industries of the 1980s and 1990s'* (Pollitt and Bouckaert 2011, p. 30). In hindsight, Peters and Savoie (1994) argue that these reforms tried to fix largely non-existent problems and overlooked the real problems. But as we learned from the process of image formation (see chapter 3), problems are subjective constructs (Kooiman 2003; Klijn and Koppenjan 2016), which makes discussions on what real problems are troublesome.

Therefore, it was a deliberate choice for the development of the SDI governing system to stay away from notions such as 'good governance' (Rhodes 1996), but use the conceptions of Kooiman to understand what enables SDI governance and what constrains it. When SDI stakeholders think there is a problem, there is a governance problem. Still, the SDI governing system framework may highlight certain features well, while others may be forgotten or neglected. Also, room for nuance may be lacking, as there are for example multiple gradations conceivable between hierarchical, network or self-organised interactions. With new ideas and theories on governance continuously developing, certain aspects in the governing system could be added, changed or become obsolete. For example, nowadays increasing attention goes to the value of data as resource for policy (Esty and Rushing 2007) and the importance of public values (Bozeman 2007) as a formalised informal structure. These aspects are not yet incorporated in the governing system framework but may be useful additions in the future.

6 With these notions in mind, the governing system framework appears to be a useful tool to provide more insight and guidance for SDI practitioners in the governing system of an SDI. It provides more structure to SDI governance research and it makes comparisons of case studies easier. Although the original aspects of the governing system are carefully selected, also the governing system framework itself must adapt to stay relevant and powerful like SDI governance. In chapter 5 we already adapted the framework to better fit the inputs of the agent-based model.

6.2.3. Agent-based modelling for SDI governance

This research used agent-based modelling for simulating SDI governance for the first time. As governance exists of interactions and agent-based modelling is highly suitable for simulating interactions, it is interesting that agent-based

modelling is hardly used for simulating governance. There could be multiple explanations for this, such as unawareness of this method by governance scholars, but probably one of the major explanations lies in the fact that governance is complex and hard to operationalise.

Also, the presented model and simulations of chapter 4 come with limitations. For example, the amount of actors and adaptive behaviour in the model is limited. Furthermore, important governance features and behaviours which are crucial in SDI governance crisis situations, such as structures as laws and policies and self-organisation, are not yet present in the model. We should be aware that like governance theories, also agent-based models can set a normative foundation based on current ideas and concepts which are dominant. Therefore, it is easy to criticise agent-based models who try to simulate governance.

However, despite these limitations, chapter 4 also shows that this does not mean that agent-based models are without value. Experts agreed that the developed model provided more insight in SDI governance. Furthermore, both the survey results and agent-based model on INSPIRE showed that the budget resources are probably its most constraining factor. The added value of agent-based modelling for simulating governance lies not in trying to predict governance, but as a tool for learning, discovering and discussion. This does not only apply to SDI practice, but also to science. By incrementally developing agent-based models around SDI governance, we cannot only make more sophisticated and realistic SDI governance models, but we will also understand SDI complexities and dynamics better.

6.2.4. Decline of the spatial data infrastructure?

In the introduction we described the rise of spatial data infrastructures from the 1990s. Currently, a decrease in research interest in SDIs is noticeable (see Figure 6.1). SDIs are now, especially in many high-income countries, well-established and not new and sexy anymore. SDI communities of science and practice, such as the Global Spatial Data Infrastructure Association (GSDI) were dissolved in 2018 (GSDI 2021). This decreased attention may be one of the biggest threats for SDIs and their governance. When attention drops in both science and practice, resources such as knowledge, funding, social and political capital may be much harder to obtain. Are we now witnessing the decline of the spatial data infrastructure?

Figure 6.1 Amount of research articles per year found with the keyword “Spatial data infrastructure” according to the database of Scopus (Elsevier 2021).

Probably not. As SDIs become more institutionalised, more trusted and especially more used, their role and importance in today’s society only becomes bigger. Like other infrastructures, SDIs are not built for a short period, but for the long-term. Although some communities of science and practice such as the GSDI are abandoned, initiatives like INSPIRE and UN-GGIM (European Commission 2021e; UN Statistics Division 2021) still give SDIs their communities for knowledge exchange.

Furthermore, the role of data in today’s society only seems to increase. For trends such as smart cities, artificial intelligence, digital twins, citizen science and data driven policies, spatial data and an adequate infrastructure is essential. Data and data science are becoming popular topics (see e.g. European Commission 2021c). To a certain extent the geo-information sector can be seen as frontrunner, as through spatial data infrastructures spatial data is much better findable, accessible and exchangeable in a standardised manner compared to other types of data.

However, we can also see that spatial data becomes less special, both on the technical and policy level. Technically, spatial data infrastructures and their standards try to incorporate web technologies such as REST API’s more (van

den Brink et al. 2019). On the policy level, we see that spatial data infrastructures become more incorporated in other forms of e-government (Sjoukema, Bregt, and Cromptvoets 2017). Furthermore, new perspectives on spatial data exchange emerge, which lead to new terms such as data platforms, data spaces and data ecosystems (Kotsev et al. 2020). It is the question to which extent these terms bring new directions for SDIs, but in many cases, they try to incorporate a more inclusive data infrastructure for citizens, public and private organisations.

Nevertheless, there is a threat that these new ideas, perspectives, developments and innovations can divert the attention from SDIs in both science and practice. This will pose challenges for SDI governance and the SDI itself. If SDIs are neglected, they may turn in legacy systems which constrains the adaptiveness of an SDI. But on the other hand, proper SDI governance can also prevent this: with different governance mixes, feedback flowing through the system, an enabling governing system and involvement of SDI stakeholders which keep each other sharp, SDIs are able to self-organise and adapt for many years to come. Therefore, it is important to keep awareness of SDIs and SDI governance high in both science and practice.

6.3. Implications for practice

This research analysed the governance dynamics of SDIs. But despite this analysis, SDI governance is still a complex subject which may puzzle most practitioners. For this section, we asked the SDI practitioners who followed this research what they learned from it. This section will provide advice for practice based on this research and their insights.

As SDI governance is a complex process, successfully designing and developing an SDI from the drawing board will be difficult. SDI governance has many interrelated developments, external surprises and non-linear dynamics, which causes their complex and dynamic behaviour. In chapter 2, we saw it can easily take 10 till 20 years from the first idea to successful SDI implementation and sometimes governance crises seemed inevitable during this long period.

Therefore, SDI governance is not static, but changes and adapts over time. This adaptive behaviour seems to be a natural feature of SDIs and their governance. However, preventing governance crises is better than solving them. When governing an SDI, anticipating pro-actively to this adaptive behaviour may be the key to prevent these crises. SDI governance should be flexible and adaptive

to cope with new developments, while its structures give it a robustness to cope with unexpected external surprises.

This is a delicate balance: overly fixing the structures such as INSPIRE (see chapter 5) will decrease the flexibility, while having little structures such as the New Map of the Netherlands (see chapter 3) poses a great risk for SDI existence. Also balancing different governance forms seems essential to increase the adaptive capacity by mixing more inclusive, bottom-up and participatory network forms of governing with hierarchical and top-down governance which can bring clarity in this complex and dynamic process. Especially the free flow of feedback is important to enable a system that learns and adapts.

The governing system framework presented in chapter 3 may help to evaluate whether the governing system of an SDI enables or constrains its adaptive behaviour. This framework facilitates a quick evaluation of the governing system of an SDI. It helps to evaluate the image around the SDI, the type of instruments used, aspects for successful implementation in action and the formal and informal structures of an SDI. To start using the governing system framework, a blank one is added as Appendix E. The framework can be used for new and existing SDIs to evaluate their governance. When done on a regular basis in a consistent manner, trends and patterns may emerge over time.

6 Although it is essential to evaluate all structures of the governing system such as laws, policies and roles and responsibilities, awareness should go to the fact that also technology and standards are structures. In many cases, these two are seen as enabling components of SDIs (see e.g. Rajabifard and Williamson 2001). But like other IT systems, also SDIs and their standards can turn into legacy systems, which will constrain the future and adaptive capacity of SDIs. This is a risk for all SDIs, even successful ones: they all need continuous evaluation and maintenance of their structures and components in order to stay adaptive for the future.

Another tool this research presents is the agent-based model to simulate SDI governance interactions. Although using agent-based models may be not on the top of mind of most SDI practitioners, it shows the effects of balancing different governance types (hierarchical, network and laissez-faire) and budget policies for the sustainability of the SDI. Even though there are much more aspects to consider in reality (see the governing system framework), these simulations

help to increase understanding and learning about SDI governance.

They further demonstrate the unexpected and stochastic behaviour of SDI governance dynamics: even with settings which gave the best performance, a run could fail quickly due to chances and coincidences. These effects also may appear in practice: even with a very enabling governing system, an SDI may fail due to bad decision making. And vice versa: without a very enabling governing system, an SDI may be a success due to for example the self-organisation of its community as in the case of the New Map of the Netherlands.

Perhaps one of the most mentioned spin-offs of this research for practice, is the increased awareness towards SDI governance. SDI experts stressed during discussions of this research and the face-validation of the agent-based model that they enjoyed discussing governance. It enabled them to reflect on SDI governance and better understand ideas and perspectives of other stakeholders. Discovering and discussing governance on a meta-level is perhaps already of much added value to many SDI communities in order to increase awareness and the adaptive capacity of SDI governance.

6.4 Research challenges for the future

Although this research helped to gain more insights in the complexities and dynamics of spatial data infrastructures, also new questions and research challenges for the future emerge. This section will explore several ideas for future research.

This research studied SDI governance from a European, mainly Dutch and Belgian, perspective. Although findings and tools from this research could be applied broader, it would be interesting to research SDI governance from other perspectives and cultures. This can be geographical, for example, countries with a larger focus on market-driven governance or countries which have less resources available, which may demand more creativity in SDI governance. But it could also look at private or self-organised SDIs instead of governmental SDIs. For example, how are Google Maps or OpenStreetMap governed and what can we learn from this?

The SDI governing system framework could be used to evaluate SDI governance in these different contexts. But this framework could also be useful for applications outside an SDI context. By testing and applying the framework with some

modifications on other types of complex systems, a generic framework with several add-ons may be developed to evaluate governing systems broader. For example, standards and technology are perhaps not for all systems necessary structures but are an essential add-on for SDIs.

Also, the use of agent-based modelling for understanding SDI governance and governance in general, could be further extended. By adding more actors, structures, adaptiveness, self-organisation and SDI features such as the growth of data supply and data use, simulations will be more realistic. As agent-based modelling is very flexible, the possibilities of this method are endless. It would be especially interesting to dive deeper in the social networks of SDI stakeholders and to simulate how these may affect SDI evolution. Also, artificial intelligence may be an useful technique to make more accurate agent-based models for simulating SDI governance scenarios (Zuiderwijk, Chen, and Salem 2021).

During the research of chapter 4, SDI experts were especially interested in the funding aspects of the agent-based model. From the expert discussions it appeared that many SDI practitioners struggle with the rising costs related to increasing SDI use. More insights in the effects of different funding models on SDI use and SDI governance will help to provide guidance in discussions on SDI funding. Also, more research on the societal value of (open) spatial data infrastructures will help in these discussions. Agent-based modelling may be an interesting approach to show both.

References

References

- Agentschap voor Geografische Informatie Vlaanderen. "Belgium - 2020: Country Fiche." European Commission, Accessed 2021-04-09. <https://inspire.ec.europa.eu/country-fiche/belgium-2020-country-fiche>.
- Alam, Shah Jamal, and Armando Geller. 2012. "Networks in agent-based social simulation." In *Agent-based models of geographical systems*, 199-216. Dordrecht: Springer Netherlands.
- Ansell, Chris, and Alison Gash. 2008. "Collaborative Governance in Theory and Practice." *Journal of Public Administration Research and Theory* 18 (4):543-71.
- Axelrod, Robert. 1997. "Advancing the Art of Simulation in the Social Sciences". In *Simulating Social Phenomena. Lecture Notes in Economics and Mathematical Systems* edited by R. Conte, R. Hegselmann and P. Terna, 21-40. Berlin, Heidelberg: Springer. https://doi.org/10.1007/978-3-662-03366-1_2.
- Bartha, Gabor, and Sandor Kocsis. 2011. "Standardization of geographic data: The european inspire directive." *European Journal of Geography* 2 (2):79-89.
- Bemelmans-Videc, Marie-Louise, Ray C. Rist, and Evert Vedung. 1998. *Carrots, sticks & sermons : policy instruments and their evaluation, Comparative policy analysis series*. New Brunswick, N.J., U.S.A.: Transaction Publishers.
- Bénabou, Roland, and Jean Tirole. 2003. "Intrinsic and Extrinsic Motivation." *The Review of Economic Studies* 70 (3):489-520. doi: 10.1111/1467-937x.00253.
- Bernard, Lars, Ioannis Kanellopoulos, Alessandro Annoni, and Paul Smits. 2005. "The European geoportal—one step towards the establishment of a European Spatial Data Infrastructure." *Computers, Environment and Urban Systems* 29 (1):15-31. doi: <https://doi.org/10.1016/j.compenvurbsys.2004.05.009>.
- Bonabeau, Eric. 2002. "Agent-based modeling: Methods and techniques for simulating human systems." *Proceedings of the National Academy of Sciences* 99 (suppl 3):7280-7. doi: 10.1073/pnas.082080899.
- Bongers, Frank, Pieter Jan de Boer, Tommy Van der Vorst, and Jessica Steur. 2019. "Evaluatie van (het gebruik van) de Risicokaart." Den Haag: Wetenschappelijk Onderzoek- en Documentatiecentrum.
- Borzacchiello, Maria Teresa, Ray Boguslawski, and Francesco Pignatelli. 2018. "New Directions in Digital Government Using INSPIRE-Report from the Workshop at the INSPIRE Conference 2017." *International Journal of Spatial Data Infrastructures Research* 13:202-22.
- Bowen, Glenn A. 2009. "Document Analysis as a Qualitative Research Method." *Qualitative Research Journal* 9 (2):27-40. doi: 10.3316/QRJ0902027.
- Box, Paul, and Abbas Rajabifard. 2009. "SDI governance bridging the gap between people and geospatial resources." In *GSDI 11 World Conference* Rotterdam, The Netherlands.
- Bozeman, Barry. 2007. *Public values and public interest: Counterbalancing economic individualism*: Georgetown University Press.
- Bregt, A.K. 2006. Value added services en de Nationale geo-informatie infrastructuur. Paper presented at the Promoting value-added GI services, Den Haag.
- Bregt, A.K., W.T. Castelein, L. Grus, and D. Eertink. 2013. "De effecten van een open

- basisregistratie topografie (BRT).” Wageningen: Wageningen University.
- Bregt, A.K., and J.W.H.C. Crompvoets. 2000. “Geo-informatie in de netwerksamenleving, een tweeluik.” In *Vi Matrix*, 16-9. VBK Content.
- Bregt, A.K., L. Grus, T. van Beuningen, and H. van Meijeren. 2016. “Wat zijn de effecten van een open Actueel Hoogtebestand Nederland (AHN)?” Wageningen: Wageningen University & Research.
- Bryman, Alan. 2012. *Social Research Methods*. 4th ed. Oxford: Oxford University Press.
- Budhathoki, Nama Raj, Bertram Bruce, and Zorica Nedovic-Budic. 2008. “Reconceptualizing the role of the user of spatial data infrastructure.” *GeoJournal* 72 (3):149-60. doi: 10.1007/s10708-008-9189-x.
- Bundesministerium für Landwirtschaft, Regionen und Tourismus (BMLRT). “Austria - 2020: Country Fiche.” European Commission, Accessed 2021-04-09. <https://inspire.ec.europa.eu/country-fiche/austria-2020-country-fiche>.
- Castells, Manuel. 1997. “An introduction to the information age.” *City* 2 (7):6-16. doi: 10.1080/13604819708900050.
- Cetl, Vlado, Robert Tomas, Alexander Kotsev, Vanda Nunes de Lima, Robin S. Smith, and Markus Jobst. 2019. “Establishing Common Ground Through INSPIRE: The Legally-Driven European Spatial Data Infrastructure.” In *Service-Oriented Mapping: Changing Paradigm in Map Production and Geoinformation Management*, edited by Jürgen Döllner, Markus Jobst and Peter Schmitz, 63-84. Cham, Switzerland: Springer International Publishing.
- Chan, Tai On, and Ian Williamson. 1999. “Spatial data infrastructure management: lessons from corporate GIS development.” In *The 27th Annual Conference of AURISA 99*. Blue Mountains, New South Wales, Australia.
- Cho, George, and Joep Crompvoets. 2019. “The INSPIRE directive: some observations on the legal framework and implementation.” *Survey Review* 51 (367):310-7. doi: 10.1080/00396265.2018.1454686.
- Coetzee, S., S. Vanlshout, R. Buyle, V. Beyaert, L. Siebritz, and J. Crompvoets. 2019. “Changing stakeholder influences in managing authoritative information – the case of the Centraal ReferentieAdressenBestand (CRAB) in Flanders.” *Journal of Spatial Science*:1-23. doi: 10.1080/14498596.2019.1650301.
- Coetzee, Serena, Martijn Odijk, Bastiaan van Loenen, Janette Storm, and Jantien Stoter. 2018. “Stakeholder analysis of the governance framework of a national SDI dataset – whose needs are met in the buildings and address register of the Netherlands?” *International Journal of Digital Earth*:1-19. doi: 10.1080/17538947.2018.1520930.
- Coetzee, Serena, and Brendon Wolff-Piggott. 2015. “A review of SDI Literature: Searching for Signs of Inverse Infrastructures.” In *Cartography - Maps Connecting the World*, edited by Claudia Robbi Sluter, Carla Bernadete Madureira Cruz and Paulo Márcio Leal de Menezes, 113-27. Cham, Switzerland: Springer International Publishing.
- Commissie Oosting. 2001. “De vuurwerkkramp: eindrapport.” Enschede/Den Haag.
- Craglia, Max, Kees de Bie, Davina Jackson, Martino Pesaresi, Gábor Remetey-Fülöpp, Changlin Wang, Alessandro Annoni, et al. 2012. “Digital Earth 2020: towards the vision for the next decade.” *International Journal of Digital Earth* 5 (1):4-

21. doi: 10.1080/17538947.2011.638500.
- Craig, William. 2005. "White knights of Spatial Data Infrastructure: The role and motivation of key individuals." *URISA journal* 16 (2):5-13.
- Crompvoets, J., A. Bregt, A. Rajabifard, and I. Williamson. 2004. "Assessing the worldwide developments of national spatial data clearinghouses." *International Journal of Geographical Information Science* 18 (7):665-89. doi: 10.1080/13658810410001702030.
- Crompvoets, Joep, Glenn Vancauwenberghe, Serene Ho, Ian Masser, and Walter Timo de Vries. 2018. "Governance of national spatial data infrastructures in Europe." *International Journal of Spatial Data Infrastructures Research* 13:253-85.
- Crooks, Andrew T., and Alison J. Heppenstall. 2012. "Introduction to Agent-Based Modelling." In *Agent-Based Models of Geographical Systems*, edited by Alison J. Heppenstall, Andrew T. Crooks, Linda M. See and Michael Batty, 85-105. Dordrecht: Springer Netherlands.
- Dang, Thi Kim Phung, Ingrid J. Visseren-Hamakers, and Bas Arts. 2015. "A framework for assessing governance capacity: An illustration from Vietnam's forestry reforms." *Environment and Planning C: Government and Policy* 34 (6):1154-74. doi: 10.1177/0263774x15598325.
- De Man, E. W. H. 2006. "Understanding SDI; complexity and institutionalization." *International Journal of Geographical Information Science* 20 (3):329-43. doi: 10.1080/13658810500399688.
- De Vries, K.G. 2001. "Vuurwerkramp Enschede. Brief van de minister van Binnenlandse Zaken en Koninkrijksrelaties." Den Haag: Ministerie van Binnenlandse Zaken en Koninkrijksrelaties.
- Dessers, Ezra, Joep Crompvoets, Katleen Janssen, Glenn Vancauwenberghe, Danny Vandenbroucke, Lieselot Vanhaverbeke, and Geert Van Hootegem. 2012. "A multidisciplinary research framework for analysing the spatial enablement of public sector processes." *International Journal of Spatial Data Infrastructures Research* 7:125-50.
- Dessers, Ezra, Glenn Vancauwenberghe, Danny Vandenbroucke, Joep Crompvoets, and Geert Van Hootegem. 2015. "Analysing spatial data performance in inter-organisational processes." *International Journal of Digital Earth* 8 (5):403-20. doi: 10.1080/17538947.2014.945499.
- Dietz, Thomas, Elinor Ostrom, and Paul C. Stern. 2003. "The Struggle to Govern the Commons." *Science* 302 (5652):1907-12. doi: 10.1126/science.1091015.
- Duit, Andreas, and Victor Galaz. 2008. "Governance and Complexity—Emerging Issues for Governance Theory." *Governance* 21 (3):311-35. doi: 10.1111/j.1468-0491.2008.00402.x.
- Edelenbos, Jurian, Arnold Bregt, Robert Broesie, Ed Dammers, Han Meyer, Dirk Neumann, and Maike Warmerdam. 2015. "An action perspective for the delta." In *New perspectives on urbanizing deltas*, edited by Han Meyer, Arnold Bregt, Ed Dammers and Jurian Edelenbos, 173-87. Amersfoort: MUST Publishers.
- Elsevier. 2021. "Scopus." Elsevier B.V. Accessed 2021-06-11. <https://www.scopus.com/home.uri>.

- Esty, Daniel, and Reece Rushing. 2007. "The Promise of Data-Driven Policymaking." *Issues in Science and Technology* 23 (4):67-72.
- European Commission. "The Digital Europe Programme." Accessed 2021-04-09. <https://digital-strategy.ec.europa.eu/en/activities/digital-programme>.
- . "A European Green Deal: Striving to be the first climate-neutral continent." Accessed 2021-04-09. https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en.
- . "A European Strategy for data." Accessed 2021-04-09. <https://digital-strategy.ec.europa.eu/en/policies/strategy-data>.
- . "Infringement Procedure." Accessed 2021-04-09. https://ec.europa.eu/info/law/law-making-process/applying-eu-law/infringement-procedure_en.
- . "INSPIRE Knowledge Base. Infrastructure for Spatial Information in Europe." Accessed 2021-04-09. <https://inspire.ec.europa.eu/>.
- . "INSPIRE Roadmap." <https://inspire.ec.europa.eu/inspire-roadmap/61>.
- . "INSPIRE work programme 2021-24." Accessed 2021-06-11. <https://webgate.ec.europa.eu/fpfis/wikis/display/InspireMIG/INSPIRE+work+programme+2021-24>.
- . "Who's who?," Accessed 2021-06-05. <https://inspire.ec.europa.eu/whos-who-inspire/57734>.
- European Parliament, and Council of the European Union. 2007. "Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE)." In *Directive 2007/2/EC*, 14. Official Journal of the European Union.
- . 2003. "Directive 2003/98/EC of the European Parliament and of the Council of 17 November 2003 on the re-use of public sector information." In *Directive 2003/98/EC*. Official Journal of the European Union.
- FO MRK projectteam, PinkRoccade, and Geodan. 2003. "Model Risicokaart Einddocument Functioneel Ontwerp." Den Haag: Ministerie van Binnenlandse Zaken en Koninkrijksrelaties.
- Fukuyama, Francis. 2013. "What is governance?" *Governance* 26 (3):347-68.
- Geluk, L.K. 2020. "VNG reactie internetconsultatie Tarievenregeling BAG en BGT." Vereniging van Nederlandse Gemeenten. Den Haag.
- Gemeente Amsterdam. "Data en informatie." Accessed 2021-04-09. <https://data.amsterdam.nl/>.
- Geographic Information Panel. 2008. "Place Matters: the Location Strategy for het United Kingdom." London: Communities and Local Government.
- Georis-Creuseveau, Jade, Christophe Claramunt, and Françoise Gourmelon. 2017. "A modelling framework for the study of Spatial Data Infrastructures applied to coastal management and planning." *International Journal of Geographical Information Science* 31 (1):122-38. doi: 10.1080/13658816.2016.1188929.
- Gerechtshof Den Haag. 2014. "Nationaal wegenbestand. Strijd met Aanwijzingen inzake verrichten marktactiviteiten door organisaties binnen de rijksdienst? Formele rechtskracht. Invloed Wet Markt en Overheid?" Den Haag: Rechtspraak.nl.
- Giddens, Anthony. 1984. *The constitution of society: Outline of the theory of*

- structuration*. Oakland, CA: University of California Press.
- Goodchild, Michael F. 2007. "Citizens as sensors: the world of volunteered geography." *GeoJournal* 69 (4):211-21. doi: 10.1007/s10708-007-9111-y.
- Gore, Al. 1994. "Creating A Government that Works Better & Costs Less. Status Report. Report of the National Performance Review." Office of the Vice President. Washington D.C.: U.S. Government Printing Office.
- Gourmelon, Françoise, Matthieu Noucher, Jade Georis-Creuseveau, Xavier Amelot, Pierre Gautreau, Grégoire Le Campion, Adeline Maulpoix, Julie Pierson, Olivier Pissot, and Mathias Rouan. 2019. "An integrated conceptual framework for SDI research: experiences from French case studies." *International Journal of Spatial Data Infrastructures Research* 14:54-82.
- Griffin, Edward, Andy Coote, and Joep Crompvoets. 2019. "A marine spatial data infrastructure in New Zealand: a systematic review on the cost-benefits." *Journal of Spatial Science* 64 (1):33-47. doi: 10.1080/14498596.2017.1372227.
- Grimm, Volker, Uta Berger, Finn Bastiansen, Sigrunn Eliassen, Vincent Ginot, Jarl Giske, John Goss-Custard, et al. 2006. "A standard protocol for describing individual-based and agent-based models." *Ecological Modelling* 198 (1):115-26. doi: <https://doi.org/10.1016/j.ecolmodel.2006.04.023>.
- Grimm, Volker, Uta Berger, Donald L. DeAngelis, J. Gary Polhill, Jarl Giske, and Steven F. Railsback. 2010. "The ODD protocol: A review and first update." *Ecological Modelling* 221 (23):2760-8. doi: <https://doi.org/10.1016/j.ecolmodel.2010.08.019>.
- Groot, Richard. 1997. "Spatial data infrastructure (SDI) for sustainable land management." *ITC journal* 3 (4):287-94.
- Grus, L., J. Crompvoets, and A. K. Bregt. 2010. "Spatial data infrastructures as complex adaptive systems." *International Journal of Geographical Information Science* 24 (3):439-63. doi: 10.1080/13658810802687319.
- GSDI. 2004. "Developing Spatial Data Infrastructures: The SDI Cookbook." Edited by Douglas D. Nebert and GSDI Technical Working Group Chair, 1-171.
- . "Global Spatial Data Association - Home." Accessed 2021-04-09. <http://gsdiassociation.org/index.php>.
- Hansen, Henning Sten, Line Hvingel, and Lise Schrøder. 2013. "Open Government Data – A Key Element in the Digital Society." In *Technology-Enabled Innovation for Democracy, Government and Governance: Second Joint International Conference on Electronic Government and the Information Systems Perspective, and Electronic Democracy, EGOVIS/EDem 2013, Prague, Czech Republic, August 26-28, 2013, Proceedings*, edited by Andrea Kő, Christine Leitner, Herbert Leitold and Alexander Prosser, 167-80. Berlin, Heidelberg: Springer Berlin Heidelberg.
- Hendriks, Paul H. J., Ezra Dessers, and Geert van Hootegeem. 2012. "Reconsidering the definition of a spatial data infrastructure." *International Journal of Geographical Information Science* 26 (8):1479-94. doi: 10.1080/13658816.2011.639301.
- Hennig, Sabine, and Mariana Belgui. 2011. "User-centric SDI: Addressing users requirements in third-generation SDI. The Example of Nature-SDIplus."

- Geoforum Perspektiv* 10 (20).
- Hjelmager, Jan, Harold Moellering, Antony Cooper, Tatiana Delgado, Abbas Rajabifard, Petr Rapant, David Danko, et al. 2008. "An initial formal model for spatial data infrastructures." *International Journal of Geographical Information Science* 22 (11-12):1295-309. doi: 10.1080/13658810801909623.
- Hood, Christopher. 1995. "The "new public management" in the 1980s: Variations on a theme." *Accounting, Organizations and Society* 20 (2):93-109. doi: [http://dx.doi.org/10.1016/0361-3682\(93\)E0001-W](http://dx.doi.org/10.1016/0361-3682(93)E0001-W).
- Hood, Christopher C. 1983. "Exploring Government's Toolshed." In *The Tools of Government*, 1-15. London: Macmillan Education UK.
- Hulsker, Walter, Joost de Koning, Maaïke Zwart, Michel Grothe, and Albert van Kempen. 2016. "Actualisatie KBA INSPIRE." Rotterdam: Ecorys.
- Informatie Vlaanderen. "Geopunt Vlaanderen." Accessed 2021-04-09. <https://www.geopunt.be/>.
- Inspectie Veiligheid en Justitie. 2013. "Scan Risicokaart. Onderzoek op hoofdlijnen naar de risicokaart." Den Haag: Inspectie Veiligheid en Justitie.
- Jessop, Bob. 2003. "Governance and meta-governance: on reflexivity, requisite variety and requisite irony." *Governance as social and political communication*:101-16.
- Kersbergen, Kees Van, and Frans Van Waarden. 2004. "'Governance' as a bridge between disciplines: Cross-disciplinary inspiration regarding shifts in governance and problems of governability, accountability and legitimacy." *European Journal of Political Research* 43 (2):143-71. doi: doi:10.1111/j.1475-6765.2004.00149.x.
- Klijn, Erik-Hans. 2008. "Governance and Governance Networks in Europe." *Public Management Review* 10 (4):505-25. doi: 10.1080/14719030802263954.
- Klijn, Erik-Hans, and Johannes Franciscus Maria Koppenjan. 2016. *Governance networks in the public sector*. Abingdon, Oxon: Routledge.
- Koerten, Henk. 2011. "Taming Technology. The narrative anchor reconciling time, territory and technology in geoinformation infrastructures." Delft University of Technology.
- Kok, Bas, and Bastiaan van Loenen. 2005. "How to assess the success of National Spatial Data Infrastructures?" *Computers, Environment and Urban Systems* 2005 (29):699-717.
- Kooiman, Jan. 1993. *Modern governance: new government-society interactions*. Edited by Jan Kooiman. London: SAGE.
- . 2003. *Governing as Governance*. London: SAGE.
- Kooiman, Jan, and Maarten Bavinck. 2013. "Theorizing Governability – The Interactive Governance Perspective." In *Governability of Fisheries and Aquaculture: Theory and Applications*, edited by Maarten Bavinck, Ratana Chuenpagdee, Svein Jentoft and Jan Kooiman, 9-30. Dordrecht: Springer Netherlands.
- Kotsev, Alexander, Marco Minghini, Robert Tomas, Vlado Cetl, and Michael Lutz. 2020. "From Spatial Data Infrastructures to Data Spaces—A Technological Perspective on the Evolution of European SDIs." *ISPRS International Journal of Geo-Information* 9 (3):176.
- Lance, K.T., Y. Georgiadou, and A.K. Bregt. 2009. "Cross-agency coordination in the

- shadow of hierarchy: 'joining up' government geospatial information systems." *International Journal of Geographical Information Science* 23 (2):249-69.
- Lee, Jae-Gil, and Minseo Kang. 2015. "Geospatial Big Data: Challenges and Opportunities." *Big Data Research* 2 (2):74-81. doi: <https://doi.org/10.1016/j.bdr.2015.01.003>.
- Lewis-Beck, Michael S., Alan Bryman, and Tim Futing Liao. 2004. "The SAGE Encyclopedia of Social Science Research Methods."607-8. doi: 10.4135/9781412950589.
- Lubida, Alex Paulo, Mohammadreza Rajabi, Petter Pilesjö, and Ali Mansourian. 2020. "Investigating an Agent Based Modelling approach for SDI planning: A case study of Tanzania NSDI development." *South African Journal of Geomatics* 9 (2):198-218.
- Macharis, Cathy, and Joep Crompvoets. 2014. "A stakeholder-based assessment framework applied to evaluate development scenarios for the spatial data infrastructure for Flanders." *Computers, Environment and Urban Systems* 46:45-56. doi: <https://doi.org/10.1016/j.compenvurbsys.2014.04.001>.
- Maguire, David J., and Paul A. Longley. 2005. "The emergence of geoportals and their role in spatial data infrastructures." *Computers, Environment and Urban Systems* 29 (1):3-14. doi: <http://dx.doi.org/10.1016/j.compenvurbsys.2004.05.012>.
- Manson, Steven M., Shipeng Sun, and Dudley Bonsal. 2012. "Agent-Based Modeling and Complexity." In *Agent-Based Models of Geographical Systems*, edited by Alison J. Heppenstall, Andrew T. Crooks, Linda M. See and Michael Batty, 125-39. Dordrecht: Springer Netherlands.
- Mansourian, Ali, and Ehsan Abdolmajidi. 2011. "Investigating the system dynamics technique for the modeling and simulation of the development of spatial data infrastructures." *International Journal of Geographical Information Science* 25 (12):2001-23. doi: 10.1080/13658816.2011.567390.
- Mansourian, Ali, Alex Lubida, Petter Pilesjö, Ehsan Abdolmajidi, and Monica Lassi. 2015. "SDI planning using the system dynamics technique within a community of practice: lessons learnt from Tanzania." *Geo-spatial Information Science* 18 (2-3):97-110. doi: 10.1080/10095020.2015.1065048.
- Masser, I. A. N. 1999. "All shapes and sizes: the first generation of national spatial data infrastructures." *International Journal of Geographical Information Science* 13 (1):67-84. doi: 10.1080/136588199241463.
- Masser, I., A. Rajabifard, and I. Williamson. 2008. "Spatially enabling governments through SDI implementation." *International Journal of Geographical Information Science* 22 (1):5-20. doi: 10.1080/13658810601177751.
- Meuleman, Louis. 2010. "The Cultural Dimension of Metagovernance: Why Governance Doctrines May Fail." *Public Organization Review* 10 (1):49-70. doi: 10.1007/s11115-009-0088-5.
- Ministerie van Binnenlandse Zaken en Koninkrijksrelaties. "DiS Geo: Doorontwikkeling in Samenhang van de Geo-basisregistraties." Accessed 2021-04-09. <https://www.geobasisregistraties.nl/basisregistraties/doorontwikkeling-in-samenhang>.
- Ministerie van Infrastructuur en Milieu. 2017. "Monitorrapportage juli 2017: BGT

- voortgang transitie." Den Haag.
- Minkov, Michael, and Geert Hofstede. 2014. "Clustering of 316 European Regions on Measures of Values." *Cross-Cultural Research* 48 (2):144-76. doi: doi:10.1177/1069397113510866.
- Mörth, Ulrika. 2009. "The Market Turn in EU Governance - The Emergence of Public-Private Collaboration." *Governance: An International Journal of Policy, Administration, and Institutions* 22 (1):99-120.
- Ngo, The An, and Linda See. 2012. "Calibration and Validation of Agent-Based Models of Land Cover Change." In *Agent-Based Models of Geographical Systems*, edited by Alison J. Heppenstall, Andrew T. Crooks, Linda M. See and Michael Batty, 181-97. Dordrecht: Springer Netherlands.
- O'Sullivan, David, James Millington, George Perry, and John Wainwright. 2012. "Agent-Based Models – Because They're Worth It?" In *Agent-Based Models of Geographical Systems*, edited by Alison J. Heppenstall, Andrew T. Crooks, Linda M. See and Michael Batty, 109-23. Dordrecht: Springer Netherlands.
- Obama, Barack. 2009. "Transparency and Open Government." E9-1777, Executive Office of the President, 2. Washington DC: Federal Register.
- Oikonomou, Iraklis. 2016. "The 'Nationalisation' of the Galileo Programme." *Theorizing European Space Policy*:141.
- Ollongren, K.H. 2020. "Concept regeling tarieven BAG BGT." WGK011544, Ministerie van Binnenlandse Zaken en Koninkrijksrelaties. Den Haag.
- Osborne, Stephen P. 2010. *The new public governance: Emerging perspectives on the theory and practice of public governance*. London: Routledge.
- PDOK. 2021. "PDOK: Hét platform voor hoogwaardige geodata." Accessed 2021-04-09. <https://www.pdok.nl/>.
- Peters, B. Guy, and Donald J. Savoie. 1994. "Civil Service Reform: Misdiagnosing the Patient." *Public Administration Review* 54 (5):418-25. doi: 10.2307/976426.
- Pierre, Jon, and B. Guy Peters. 2005. *Governing complex societies: Trajectories and scenarios*. Basingstoke: Palgrave Macmillan UK.
- Pollitt, Christopher, and Geert Bouckaert. 2011. *Public Management Reform. A Comparative Analysis: New Public Management, Governance, and the Neo-Weberian State*. New York: Oxford University Press.
- PricewaterhouseCoopers. 2017. "The impact of the open geographical data - follow up study." Denmark: Agency for Data Supply and Efficiency.
- Rajabifard, A., M.E. Feeney, I. Williamson, and I. Masser. 2003. "National SDI Initiatives." In *Developing Spatial Data Infrastructures: From Concept to Reality*, edited by Ian Williamson, Abbas Rajabifard and Mary-Ellen F. Feeney, 99-114. London: Taylor & Francis.
- Rajabifard, Abbas, Mary-Ellen F. Feeney, and Ian P. Williamson. 2002. "Future directions for SDI development." *International Journal of Applied Earth Observation and Geoinformation* 4 (1):11-22. doi: [https://doi.org/10.1016/S0303-2434\(02\)00002-8](https://doi.org/10.1016/S0303-2434(02)00002-8).
- Rajabifard, Abbas, and Ian P Williamson. 2001. "Spatial data infrastructures: concept, SDI hierarchy and future directions." In *Proceedings of GEOMATICS'80 Conference*. Teheran.
- Rand, William, and Roland T. Rust. 2011. "Agent-based modeling in marketing:

- Guidelines for rigor." *International Journal of Research in Marketing* 28 (3):181-93. doi: <https://doi.org/10.1016/j.ijresmar.2011.04.002>.
- Rhodes, R. A. W. 1996. "The New Governance: Governing without Government." *Political Studies* 44 (4):652-67. doi: 10.1111/j.1467-9248.1996.tb01747.x.
- Richter, Christine, Gianluca Miscione, and Yola Georgiadou. 2010. "Conceptualizing people in SDI literature: Implications for SDI research and development." *International Journal of Spatial Data Infrastructures Research* 5 (5):286-325.
- Rijke, Jeroen, Rebekah Brown, Chirs Zevenbergen, Richard Ashley, Megan Farelly, Peter Morison, and Sebastiaan van Herk. 2012. "Fit-for-purpose governance: A framework to make adaptive governance operational." *Environmental Science & Policy* 22:73-84.
- Robichau, Robbie Waters. 2011. "The Mosaic of Governance: Creating a Picture with Definitions, Theories, and Debates." *The Policy Studies Journal* 39 (S1):113-31.
- Rowley, Jennifer. 2007. "The wisdom hierarchy: representations of the DIKW hierarchy." *Journal of Information Science* 33 (2):163-80. doi: 10.1177/0165551506070706.
- Sanz, Esteve. 2014. "Open Governments and Their Cultural Transitions." In *Open Government: Opportunities and Challenges for Public Governance*, edited by Mila Gascó-Hernández, 1-15. New York, NY: Springer New York.
- Scott, John. 1990. *A matter of record*. Cambridge: Polity Press.
- Sewell, William H. 1992. "A Theory of Structure: Duality, Agency, and Transformation." *American Journal of Sociology* 98 (1):1-29.
- Sjoukema, Jaap-Willem, Arnold Bregt, and Joep Crompvoets. 2017. "Evolving Spatial Data Infrastructures and the Role of Adaptive Governance." *ISPRS International Journal of Geo-Information* 6 (8):254. doi: <https://doi.org/10.3390/ijgi6080254>.
- Sjoukema, Jaap-Willem, Arnold K Bregt, and Joep Crompvoets. 2020. "Understanding Governance Dynamics: The Governing System of Spatial Data Infrastructures." *International Journal of Spatial Data Infrastructures Research* 15. doi: 10.2902/1725-0463.2020.15.art1.
- Sjoukema, Jaap-Willem, Jalal Samia, Arnold K. Bregt, and Joep Crompvoets. 2021. "Governance interactions of spatial data infrastructures: an agent-based modelling approach." *International Journal of Digital Earth* 14 (6):696-713. doi: 10.1080/17538947.2020.1868585.
- Steiniger, Stefan, and Andrew J. S. Hunter. 2012. "Free and Open Source GIS Software for Building a Spatial Data Infrastructure." In *Geospatial Free and Open Source Software in the 21st Century: Proceedings of the first Open Source Geospatial Research Symposium, OGRS 2009*, edited by Erwan Bocher and Markus Neteler, 247-61. Berlin, Heidelberg: Springer Berlin Heidelberg.
- Teisman, Geert R. 2000. "Models For Research into Decision-Making Processes: On Phases, Streams and Decision-Making Rounds." *Public Administration* 78 (4):937-56. doi: 10.1111/1467-9299.00238.
- The White House. 1994. "Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure." *Executive Order 12906*, The President.

- Federal Register.
- Tripathi, Ashutosh Kumar, Sonam Agrawal, and R. D. Gupta. 2020. "Cloud enabled SDI architecture: a review." *Earth Science Informatics* 13 (2):211-31. doi: 10.1007/s12145-020-00446-9.
- UN-GGIM. 2017. "National Institutional Arrangements: Instruments, Principles and Guidelines." In, 1-24. United Nations Committee of Experts on Global Geospatial Information Management.
- . 2018. "Integrated Geospatial Information Framework: A Strategic Guide To Develop And Strengthen National Geospatial Information Management. Part 1: Overarching Strategic Framework." New York: United Nations Statistics Division.
- UN Statistics Division. "UN-GGIM." Accessed 2021-04-09. <https://ggim.un.org/>.
- Van Arragon, Johan, Ad van Houtum, Christiaan de Jong, Piet Hein Minnecre, and Ine de Visser. 2019. "Visie INSPIRE. Van sturen op implementatie naar sturen op de baten." Amersfoort: Geonovum.
- van den Brink, Linda, Payam Barnaghi, Jeremy Tandy, Ghislain Atemezang, Rob Atkinson, Byron Cochrane, Yasmin Fathy, et al. 2019. "Best practices for publishing, retrieving, and using spatial data on the web." *Semantic Web* 10:95-114. doi: 10.3233/SW-180305.
- Van Loenen, Bastiaan, and Michel Grothe. 2014. "INSPIRE empowers re-use of public sector information." *International Journal of Spatial Data Infrastructures Research* 9:96-106.
- Vancauwenberghe, Glenn. 2013. "Coordination within Spatial Data Infrastructures: An analysis of exchange and use of geographical information in Flanders." KU Leuven.
- Vancauwenberghe, Glenn, Kotryna Valečkaitė, Bastiaan van Loenen, and Frederika Welle Donker. 2018. "Assessing the Openness of Spatial Data Infrastructures (SDI): Towards a Map of Open SDI." *International Journal of Spatial Data Infrastructures Research* 13:88-100.
- Vancauwenberghe, Glenn, and Bastiaan van Loenen. 2017. "Governance of open spatial data infrastructures in Europe." In *The Social Dynamics of Open Data*, edited by Francois van Schalkwyk, Stefaan G Verhulst, Gustavo Magalhaes, Juan Pane and Johanna Walker, 63-88. Cape Town: African Minds.
- . 2018. "Exploring the Emergence of Open Spatial Data Infrastructures: Analysis of Recent Developments and Trends in Europe." In *User Centric E-Government: Challenges and Opportunities*, edited by Saqib Saeed, T. Ramayah and Zaigham Mahmood, 23-45. Cham, Switzerland: Springer International Publishing.
- Vandenbroucke, Danny, Joep Crompvoets, Glenn Vancauwenberghe, Ezra Dessers, and Jos Van Orshoven. 2009. "A Network Perspective on Spatial Data Infrastructures: Application to the Sub-national SDI of Flanders (Belgium)." *Transactions in GIS* 13:105-22. doi: 10.1111/j.1467-9671.2009.01166.x.
- Verhoest, Koen, Geert Bouckaert, and B. Guy Peters. 2007. "Janus-faced reorganization: specialization and coordination in four OECD countries in the period 1980—2005." *International Review of Administrative Sciences* 73 (3):325-48. doi: 10.1177/0020852307081144.

- Vlaamse Raad. 1992. "Handelingen 7-8-9-10-11, Vergaderingen van november 1992." 237-54. Brussel.
- Welle Donker, F.M. 2016. "From Access to Re-use: A user's perspective on public sector availability." A+BE | Architecture and the Built Environment.
- Welle Donker, F.M., B. van Loenen, and W.K. Korthals Altes. 2017. "Maatschappelijke kosten-batenanalyse open data." Delft: OTB-Onderzoek voor de gebouwde omgeving. Faculteit Bouwkunde, TU Delft.
- Welle Donker, Frederika. 2009. "Public Sector Geo Web Services: Which Business Model Will Pay for a Free Lunch?" In *SDI Convergence. Research, Emerging Trends, and Critical Assessment*, edited by J.W.J. Besemer B. van Loenen, J.A. Zevenbergen, 35-50. Delft: Optima Grafische Communicatie.
- Welle Donker, Frederika, and Bastiaan Van Loenen. 2016. "Sustainable Business Models for Public Sector Open Data Providers." *JeDEM - eJournal of eDemocracy and Open Government* 8 (1). doi: 10.29379/jedem.v8i1.390.
- . 2017. "How to assess the success of the open data ecosystem?" *International Journal of Digital Earth* 10 (3):284-306. doi: 10.1080/17538947.2016.1224938.
- Wilensky, Uri. 1999. "NetLogo." Evanston, Illinois: Center for Connected Learning and Computer-Based Modeling, Northwestern University.
- Worthy, Ben. 2010. "More Open but Not More Trusted? The Effect of the Freedom of Information Act 2000 on the United Kingdom Central Government." *Governance* 23 (4):561-82. doi: 10.1111/j.1468-0491.2010.01498.x.
- Zuiderwijk, Anneke, Yu-Che Chen, and Fadi Salem. 2021. "Implications of the use of artificial intelligence in public governance: A systematic literature review and a research agenda." *Government Information Quarterly*:101577. doi: <https://doi.org/10.1016/j.giq.2021.101577>.

Appendices

Appendix A. Geo-information magazine articles referred to

List of geo-information magazine articles used for the document analysis of chapter 2.

- 1971a, Studiecommissie Leidingenregistratie. Rapport Studiecommissie Leidingenregistratie. NGT, Vol. 1971, No. 05, pp. 91–105.
- 1971b, D.L. Rodrigues Lopes. De studiedag leidingenregistratie. NGT, Vol. 1971, No. 09, pp. 148–153.
- 1972a, G.A. van Wely. Grootschalige basiskaart van Nederland. Geodesia, Vol. 1972, No. 07, p. 200.
- 1972b, G.A. van Wely. Grootschalige basiskaart van Nederland. NGT, Vol. 1972, No. 09, pp. 144–145.
- 1973a, M.J.M. Bogaerts, G.F. de Witt, C. Koeman, G.A. van Wely, W.A. Claessen, S. Rienstra, J.A.C.E. van Roermund. Interimrapport Commissie Grootschalige basiskaart. NGT, Vol. 1973, No. 09, pp. 130–135.
- 1973b, C. Zeillemaker. Voorstellen voor de normalisatie van de bladindeling, het formaat en de nummering van grootschalige (1:2000 tot 1:500) topografische kaarten. NGT, Vol. 1973, No. 10, pp. 159–165.
- 1973c, C. Koeman. Voorstel voor bladindeling, het formaat en de nummering van de Nederlandse grootschalige kaart. NGT, Vol. 1973, No. 12, pp. 212–215.
- 1973d, J. Dubbeld. Digitaal kaarteren. NGT, Vol. 1973, No. 05, pp. 85–95.
- 1973e, Projectgroep '73. Digitale basiskaartering. Geodesia, Vol. 1973, No. 06, pp. 130–131.
- 1973f, Projectgroep '73. Het rapport 'Digitale Basiskaartering' van de projectgroep '73 van de onderafdeling der Geodesie, TH-Delft. NGT, Vol. 1973, No. 09, p. 141.
- 1974a, M.J.M. Bogaerts, G.F. de Witt, C. Koeman, G.A. van Wely, P.A.M. de Vos, J.B. van Reij, W.A. Claessen, S. Rienstra, A. Waalewijn, J.A.C.E. van Roermund. Rapport van de commissie Grootschalige basiskaart. NGT, Vol. 1974, No. 11, pp. 219–237.
- 1975a, Editors. Grootschalige Basiskaart. Geodesia, Vol. 1975, No. 07, pp. 186–187.
- 1975b, Editors. Grootschalige Basiskaart. NGT, Vol. 1975, No. 09, pp. 145–146.
- 1976a, J.P. Gruijters, G.A. van Wely. Installatie centrale kaarteringsraad. Geodesia, Vol. 1976, No. 03, pp. 90–93.
- 1976b, J.P. Gruijters. Installatie centrale kaarteringsraad. NGT, Vol. 1976, No. 03, pp. 57–58.
- 1976c, W.A. Claessen. Grootschalige Basiskaart 'het Bildt. Geodesia, Vol. 1976, No. 02, pp. 58–59.
- 1976d, W.A. Claessen. Grootschalige Basiskaart 'het Bildt. NGT, Vol. 1976, No. 02, p. 38.
- 1977, P. Plantinga. GBKN proefproject het Bildt. NGT, Vol. 1977, No. 06, pp. 97–109.
- 1978, G.A van Wely. De vorming van Provinciale Kaarteringscommissies. Geodesia, Vol. 1978, No. 05, pp. 127–130.
- 1980, Unknown. Jaarverslag 1979 Voorlopige Centrale Kaarteringsraad. Geodesia, Vol. 1980, No. 11, p. 435.

- 1983, Unknown. Advies van de voorlopige Centrale Kaarteringsraad. *Geodesia*, Vol. 1983, No. 09, p. 283.
- 1984a, J. Mol. Heeft het Structuurplan Topografie en Leidingen van de BOCO zin? *Geodesia*, Vol. 1984, No. 01, pp. 9–11.
- 1984b, Unknown. Jaarverslag 1983 Voorlopige Centrale Kaarteringsraad. *Geodesia*, Vol. 1984, No. 09, pp. 311–312.
- 1984c, P. van der Molen. Privatisering van overheidstaken op het gebied van de landmeetkunde en kartografie. *Geodesia*, Vol. 1984, No. 07, pp. 248–254.
- 1984d, A.J.G. Zinken. Decentralisatie kadastertaken. *Geodesia*, Vol. 1984, No. 10, pp. 345–347.
- 1985a, J.L.G. Henssen. De ontwerp-Kadasterwet. *Geodesia*, Vol. 1985, No. 11, pp. 386–390.
- 1985b, C.J. Remijnse. Het Kadaster als producent en verstrekker van vastgoedinformatie. *Geodesia*, Vol. 1985, No. 12, pp. 440–441.
- 1986a, F.B. Uit de Nieuwjaarstoespraken. *Geodesia*, Vol. 1986, No. 03, pp. 102–103.
- 1986b, Adri den Boer. GBKN-B een haalbare kaart. *Geodesia*, Vol. 1986, No. 06, pp. 224–225.
- 1987a, Peter Miete. Het grote geld. *Geodesia*, Vol. 1987, No. 12, p. 526.
- 1987b, J.B. van der Veen. De ontwikkeling van de GBKN in Overijssel. *Geodesia*, Vol. 1987, No. 02, pp. 47–51.
- 1988, Editors. Onderzoek naar gebruik en kosten van de grootschalige basiskaart Nederland. *Geodesia*, Vol. 1988, No. 07, p. 348.
- 1989a, J.W.J. Besemer, F.v.d. Gaag, W. van Pijkeren, J.H.J.M. Vos. Het Kadaster op weg naar de formatie 1990. *Geodesia*, Vol. 1989, No. 04, pp. 166–170.
- 1989b, L.A.H. Boeije. De toekomstige rol van de grootschalige basiskaart bij de gemeente. *Geodesia*, Vol. 1989, No. 02, pp. 71–76.
- 1989c, G.P.F. Pistorius. De relatie tussen de nutsbedrijven en de GBKN. *Geodesia*, Vol. 1989, No. 03, pp. 124–126.
- 1990a, J.G. Versteeg. Een pleidooi voor een betere bijhoudingsregeling GBKN. *Geodesia*, Vol. 1990, No. 03, pp. 114–118.
- 1990b, C. Zeillemaker. Gemeenten en topografie. *Geodesia*, Vol. 1990, No. 09, pp. 369–373.
- 1991a, Unknown. Privatisering Kadaster nu op een laag pitje. *Geodesia*, Vol. 1991, No. 01, p. 84.
- 1991b, J. Besemer, Wim van Pijkeren, Theo Scheele. De (onzekere) toekomst van het Kadaster. *Geodesia*, Vol. 1991, No. 06, pp. 258–261.
- 1991c, Editors. Kadaster. *Geodesia*, Vol. 1991, No. 12, p. 555.
- 1992a, Adri den Boer. Ministerraad akkoord met wetsvoorstel verzelfstandiging Kadaster. *Geodesia*, Vol. 1992, No. 07, pp. 310–311.
- 1992b, Berry van Osch. GBKN-overleg in impasse?. *Geodesia*, Vol. 1992, No. 04, pp. 160–163.
- 1992c, P. Schreuder, Z. Klaasse. Kadasterwet. *Geodesia*, Vol. 1992, No. 09, pp. 344–353.
- 1992d, R. Morrema. GBKN-PPP Op weg naar publiek private samenwerking. *Geodesia*, Vol. 1992, No. 04, pp. 142–146.
- 1992e, Unknown. Samenwerkingscontract Grootschalige Basiskaart van Nederland

- ondertekend. *Geodesia*, Vol. 1992, No. 12, p. 535.
- 1993a, Editors. De strijd om tien miljoen. *Geodesia*, Vol. 1993, No. 05, p. 227.
- 1993b, J. Kats. Grootchalige Basiskaart van Nederland: strijd om tien miljoen?. *Geodesia*, Vol. 1993, No. 09, p. 425.
- 1993c, F. Molenaars, J.A. Schaart. GBKN een zorgkind volwassen. *Geodesia*, Vol. 1993, No. 04, pp. 160–164.
- 1993d, W.H. de Vos. Landelijk Samenwerkingsverband GBKN. *Geodesia*, Vol. 1993, No. 11, pp. 558–564.
- 1993e, J.H. van Oogen. Terreinmodel Vastgoed. Een algemene classificatie voor ruimtelijke objecten. *Geodesia*, Vol. 1993, No. 10, pp. 486–490.
- 1993f, Peter Mom. Over jaar of 10 is gans Vlaanderen gecardibd. *Vi Matrix*, Vol. 1993, No. 12, pp. 10–13.
- 1993g, Peter Mom, Vera Dua. Gewest zal nooit over eigen basisgegevens beschikken. *Vi Matrix*, Vol. 1993, No. 10, pp. 36–37.
- 1993h, Editors. GIS in België: verdeeldheid troef. *Vi Matrix*, Vol. 1993, No. 12, p. 49.
- 1993i, Peter Mom. Tien profs tekenen bestek voor een Vlaams 'GIS-huis'. *Vi Matrix*, Vol. 1993, No. 10, pp. 34–35.
- 1994a, Peter Mom. Belgacom talmt met participatie Cardib. *Vi Matrix*, Vol. 1994, No. 03, p. 42.
- 1994b, Peter Mom. Cardib valt van de ene verbazing in de andere. *Vi Matrix*, Vol. 1994, No. 12, pp. 38–39.
- 1994c, Peter Mom. Slechten GIS-barrière plaatst gemeenten voor nieuw obstakel. *Vi Matrix*, Vol. 1994, No. 03, pp. 20–23.
- 1994d, Peter Mom. Weg vrij voor GIS-Vlaanderen. *Vi Matrix*, Vol. 1994, No. 06, pp. 44–44.
- 1994e, Peter Mom. Vlaamse GIS-werkgroep vergadert hevig voort. *Vi Matrix*, Vol. 1994, No. 10, pp. 2–3.
- 1994f, Peter Mom. Optimisme over GIS Vlaanderen moet men soms van verre zoeken. *Vi Matrix*, Vol. 1994, No. 10, pp. 6–7.
- 1995a, J.B. van der Veen, H.T. Uitermark. Naar een objectgerichte GBKN?! Van basiskaart tot basisbestand via het objectbegrip. *Geodesia*, Vol. 1995, No. 02, pp. 83–88.
- 1995b, C.H.J. Lemmen. Topologie en unike objectidentificatie. Enige aspecten bij het uitwisselen van ruimtelijke gegevens. *Geodesia*, Vol. 1995, No. 05, pp. 231–235.
- 1995c, Peter Mom. GIS-Vlaanderen krijgt stilaan de allure van een fata morgana. *Vi Matrix*, Vol. 1995, No. 01, pp. 6–9.
- 1995d, Peter Mom. Regeringsbesluit GIS-Vlaanderen. *Vi Matrix*, Vol. 1995, No. 06, p. 47.
- 1996a, Berry van Osch. Van de redactie: De objectgerichte GBKN: wanneer komt er schot in?. *Geodesia*, Vol. 1996, No. 04, p. 138.
- 1996b, Theo Scheele. Themadag Objectgerichte GBKN in Zeeland. *Geodesia*, Vol. 1996, No. 12, pp. 553–554.
- 1997a, Ad van der Meer. Van de redactie: Objectgerichte GBKN als religieus dispuut. *Geodesia*, Vol. 1997, No. 04, p. 154.
- 1997b, Jaap van der Veen. Objectgerichtheid en de GBKN. Een manier om tot

- standaardisatie te komen. *Geodesia*, Vol. 1997, No. 05, pp. 227–228.
- 1997c, Berry van Osch. Zijn we wel klaar voor een Objectgerichte GBKN?. *Geodesia*, Vol. 1997, No. 07, p. 298.
- 1997d, René van der Schans. We zijn niet klaar voor een objectgerichte GBKN. Een reactie op Berry van Osch' redactionele commentaar. *Geodesia*, Vol. 1997, No. 09, p. 397.
- 1997e, Peter Mom. Cardib onvermoeid optimistisch over Grootschalige BasisKaart Vlaanderen. *Vi Matrix*, Vol. 1997, No. 02, pp. 33–35.
- 1997f, Peter Mom. Interelectra gaat nu met 'Cardib-kaart' eigen weg. *Vi Matrix*, Vol. 1997, No. 09, pp. 40–42.
- 1997g, Peter Mom. Cardib en OC optimistisch over één grootschalige basiskaart. *Vi Matrix*, Vol. 1997, No. 12, p. 43.
- 1998, LSV-GBKN. Objectgerichte GBKN voorlopig geen haalbare kaart. *Geodesia*, Vol. 1998, No. 01, p. 42.
- 1999a, Landelijk Samenwerkingsverband GBKN. GBKN-vervaardiging bijna gereed. *Geodesia*, Vol. 1999, No. 06, p. 297.
- 1999b, J.C. Meerkerk, J.B. van der Veen. De GBKN, klaar voor de 21ste eeuw!?. *Geodesia*, Vol. 1999, No. 04, pp. 163–169.
- 1999c, Peter Mom. OC start scanproject. *Vi Matrix*, Vol. 1999, No. 02, p. 36.
- 1999d, Peter Mom. Grootschalig Referentie Bestand voor Vlaanderen haalbare kaart. *Vi Matrix*, Vol. 1999, No. 12, pp. 38–40.
- 1999e, Peter Gorlé. Samenwerking GIS-Vlaanderen krijgt decretale basis. *Vi Matrix*, Vol. 1999, No. 09, pp. 34–37.
- 2000a, J. Polman. Hink, Stap, Sprong. De geschiedenis van het ontstaan van de GBKN. *Geodesia*, Vol. 2000, No. 07, pp. 319–326.
- 2000b, L.M. Murre. GBKN anno 2000. De stand van zaken en het perspectief voor de toekomst. *Geodesia*, Vol. 2000, No. 07, pp. 327–332.
- 2000c, Editors. GIS bij wet geregeld. *Vi Matrix*, Vol. 2000, No. 09, p. 41.
- 2001a, L.M. Murre. Laatste GBKN in Hardinxveld/Giessendam opgeleverd. *Geodesia*, Vol. 2001, No. 02, p. 83.
- 2001b, J.C. Meerkerk, J.W.F.M. van Grunsven. GBKN, van aanbod naar vraaggericht. *Geodesia*, Vol. 2001, No. 03, pp. 117–121.
- 2001c, LSV-GBKN. Berichten uit de Stuurgroep GBKN. *Geodesia*, Vol. 2001, No. 12, p. 600.
- 2001d, Peter Mom. GRB Vlaanderen staat op de rails. *Vi Matrix*, Vol. 2001, No. 12, pp. 28–30.
- 2002a, Ad van der Meer. De GBKN een authentieke registratie? *Geodesia*, Vol. 2002, No. 06, p. 235.
- 2002b, Ad van der Meer. De GBKN-kip en het AR-ei. *Geodesia*, Vol. 2002, No. 09, p. 327.
- 2002c, N.J.M. van Eekelen, E.J.M. Weesie. Instrumenten voor een uniforme GBKN. *Geodesia*, Vol. 2002, No. 03, pp. 108–110.
- 2002d, Adri den Boer. Geo-informatiebeleid in Tweede Kamer. *Geodesia*, Vol. 2002, No. 09, pp. 322–326.
- 2002e, Leen Murre. Topografie en gemeenten. *Geodesia*, Vol. 2002, No. 10, p. 387.
- 2002f, Peter Mom. Londerzeel prijst de dag dat GRB wordt opgeleverd. *Vi Matrix*, Vol.

- 2002, No. 06, pp. 30–31.
- 2003a, H. Schallenberg. De grootschalige basiskaart een gemeentelijke zorg. *Geodesia*, Vol. 2003, No. 01, pp. 4–9.
- 2003b, L.M. Murre. Nieuwe Stichting LSV GBKN van start. *Geodesia*, Vol. 2003, No. 09, pp. 342–345.
- 2003c, Adri den Boer. Eindrapportage Stroomlijning Basisgegevens. *Geodesia*, Vol. 2003, No. 05, pp. 210–212.
- 2003d, E. Scheltes, L.A. Smit, Ad van der Meer, Jan de Kruif. Gemeenten verantwoordelijk voor topografie'. *Geodesia*, Vol. 2003, No. 02, pp. 82–85.
- 2003e, L.M. Murre. Kunnen 'gemeenten verantwoordelijk zijn voor topografie'?. *Geodesia*, Vol. 2003, No. 04, p. 179.
- 2003f, E. Dolle. RSV en TPG sluiten aan. *Geodesia*, Vol. 2003, No. 11, p. 457.
- 2004, Peter Mom. GRB-primeur voor Geetbets. *Vi Matrix*, Vol. 2004, No. 11, pp. 47–48.
- 2005, Redactie. Minister Kris Peeters volgt realisatie van geo-basisbestanden met argusogen. *Vi Matrix*, Vol. 2005, No. 12, pp. 44–47.
- 2006a, Adri den Boer. Themabijeenkomst basisregistraties in trek. *Geo-info*, Vol. 2006, No. 07, pp. 314–316.
- 2006b, L.M. Murre. Wordt de GBKN een basisregistratie?. *Geo-info*, Vol. 2006, No. 02, pp. 66–68.
- 2006c, Koen Vervloessem. Iedereen een gelijke manier van aanmeten en alle objecten in de juiste layer. *Geoplatform*, Vol. 2006, No. 09, pp. 6–9.
- 2006d, Peter van Es. GIS Vlaanderen: verleden, heden en toekomst. *Geoplatform*, Vol. 2006, No. 09, pp. 10–15.
- 2009a, Adri den Boer, Martin Peersmann. Martin Peersmann: 11 maanden 'mister GBKN2BGT'. *Geo-info*, Vol. 2009, No. 10, pp. 4–6.
- 2009c, Nico vande Kerkhof. Vlaanderen moet leren omgaan met een gefaseerde GRB-realisatie. *Geoplatform*, Vol. 2009, No. 09, pp. 14–19.
- 2009b, Ronald Bokhove. Gemeenten kleuren de BGT in, maar hoe?. *Geo-info*, Vol. 2009, No. 11, pp. 30–32.
- 2010, Adri den Boer, Ruud van Rossem. Ruud van Rossem: nu mister BGT. *Geo-info*, Vol. 2010, No. 01, pp. 22–24.
- 2011, Adri den Boer. Bronhoudersoverleg BGT op naar uniformering. *Geo-info*, Vol. 2011, No. 07, pp. 21–22.
- 2012a, Ruud van Rossem. De BGT: van denken naar doen. *Geo-info*, Vol. 2012, No. 06, pp. 4–8.
- 2012b, Bart Maessen. Landelijke voorziening BGT. *Geo-info*, Vol. 2012, No. 06, pp. 22–24.
- 2012c, Ernst Koperdraat. Nut en noodzaak van een samenwerkingsverband van bronhouders. *Geo-info*, Vol. 2012, No. 06, pp. 26–29.
- 2012d, Martin Peersmann, Sieb Dijkstra. Van GBKN naar BGT in historisch perspectief. *Geo-info*, Vol. 2012, No. 6, pp. 38–42.
- 2013, Editors. Wet BGT door de Eerste Kamer. *Geo-info*, Vol. 2013, No. 08, p. 44.
- 2014, BGTweb. Valkenswaard als eerste helemaal in de BGT!. *Geo-info*, Vol. 2014, No. 06, p. 15.
- 2016, Roelof Keppel. Verslag FLAGIS-bijeenkomst 8 december 2015 te Lier (B). *Geo-*

- info, Vol. 2016, No. 01, p. 34.
- 2017a, Roelof Keppel; Astrid van den Hoek, Nienke Zeijlemaker. Grip op data: de puzzel van Rijkswaterstaat. Geo-info, Vol. 2017, No. 03, pp. 24–27.
- 2017b, Marcel Rietdijk; Gerlof de haan; Sandra Leijten. Met de BGT op tijdreis door de openbare ruimte. Geo-info, Vol. 2017, No. 03, pp. 30–33.

Appendix B. Coding results per case and round

Tables showing the coding results per case of chapter 3. First the absolute amount of code frequencies per round is shown. Thereafter, two indicators are shown. The first indicator is calculated by calculating a percentage of a code compared to the total amount of codes per round. This calculation is done for both rounds and then this percentage is subtracted from each other, resulting in the percentage shown in the column 'relative difference between rounds'. When the difference is more than 0.5% or -0.5%, the number is shown in bold. The second indicator is calculated in the same way, but then the percentage is calculated compared to the total amount of codes within a round per category (e.g. 'action'). Again, these percentages are subtracted, resulting in the indicator shown in the column 'relative difference within category'. When the difference is more than 1.5% or -1.5% the number is shown in bold.

Table B.1. Code frequencies of the Risk Map.

Category	Code	Attribute	Risk Map Round 1	Risk Map Round 2	Relative difference between rounds	Relative difference within category
Action	Collaboration	Present	35	26	-1.8%	-12.3%
		Lacking	17	23	-0.4%	-1.2%
	Coordination	Present	11	36	0.8%	8.9%
		Lacking	40	58	-0.7%	-1.1%
	Leadership	Present	9	15	-0.1%	0.6%
		Lacking	3	20	0.7%	7.1%
	Self-organisation	Present	25	40	-0.3%	1.0%
		Lacking	5	1	-0.4%	-3.0%
Image	Collaborative	Aligned	21	43	0.2%	0.0%
		Unaligned	30	33	-1.0%	-5.8%
	Feedback	Negative	39	67	-0.2%	-2.6%
		Positive	23	53	0.5%	1.2%
	Goal/vision	Explicit	61	71	-1.9%	-11.0%
		Individual	18	97	3.0%	12.3%
	Satisfaction	Negative	31	80	1.1%	3.4%
		Positive	16	45	0.8%	2.5%

Category	Code	Attribute	Risk Map Round 1	Risk Map Round 2	Relative difference between rounds	Relative difference within category
Interaction	Bottom-up	Interference	7	25	0.6%	7.7%
		Interplay	32	75	0.8%	13.0%
		Intervention	4	8	0.0%	0.8%
	Top-down	Interference	0	9	0.4%	5.1%
		Interplay	30	43	-0.6%	-3.3%
		Intervention	35	16	-2.3%	-23.3%
Instrument	Detector	Information	10	32	0.7%	6.4%
		Organisation	28	67	0.8%	10.3%
		Rule	17	5	-1.2%	-5.9%
	Effector	Information	43	50	-1.3%	-2.2%
		Organisation	74	123	-0.6%	8.8%
		Rule	52	17	-3.7%	-17.4%
SDI qualities	Data provision	Bad	12	12	-0.5%	-13.6%
		Good	9	8	-0.4%	-11.0%
	Data quality/ availability	Bad	15	40	0.6%	3.6%
		Good	4	13	0.3%	2.9%
	Use	Non use	2	15	0.5%	8.5%
		Use	9	33	0.8%	9.6%
Structures	Roles and responsibilities	Enabling	57	112	0.4%	-0.7%
		Constraining	43	69	-0.4%	-2.5%
	Budget resources	Enabling	11	28	0.4%	0.6%
		Constraining	6	37	1.2%	3.0%
	Culture	Enabling	2	0	-0.2%	-0.5%
		Constraining	6	5	-0.3%	-0.9%
	Knowledge resources	Enabling	12	37	0.7%	1.5%
		Constraining	9	19	0.1%	0.0%
	Law	Enabling	54	70	-1.3%	-5.1%
		Constraining	13	45	1.0%	2.2%
	Ownership	Enabling	12	29	0.3%	0.5%
		Constraining	8	23	0.4%	0.8%
	Political capital	Enabling	20	43	0.3%	0.2%
		Constraining	6	23	0.6%	1.3%

Category	Code	Attribute	Risk Map Round 1	Risk Map Round 2	Relative difference between rounds	Relative difference within category
Structures	Social capital	Enabling	1	15	0.6%	1.6%
		Constraining	0	2	0.1%	0.2%
	Standards	Enabling	26	9	-1.8%	-5.5%
		Constraining	9	21	0.2%	0.3%
	Support	Enabling	14	37	0.5%	1.0%
		Constraining	8	50	1.7%	4.1%
	Technology	Enabling	28	24	-1.3%	-4.2%
		Constraining	23	49	0.3%	0.2%
	Time resources	Enabling	3	11	0.3%	0.6%
		Constraining	2	24	1.0%	2.4%
	Trust	Enabling	1	7	0.2%	0.6%
		Constraining	18	22	-0.5%	-1.9%
Total			1159	2110		

Table B.2. Code frequencies of the New Map of the Netherlands.

Category	Code	Attribute	New Map Round 1	New Map Round 2	Relative difference between rounds	Relative difference within category
Action	Collaboration	Present	13	32	0.7%	1.1%
		Lacking	9	22	0.5%	0.7%
	Coordination	Present	15	10	-1.0%	-12.0%
		Lacking	5	22	0.9%	5.2%
	Leadership	Present	9	29	1.0%	4.1%
		Lacking	1	2	0.0%	-0.1%
	Self-organisation	Present	34	83	1.8%	2.5%
		Lacking	3	4	-0.1%	-1.4%
Image	Collaborative	Aligned	7	5	-0.4%	-2.4%
		Unaligned	10	43	1.8%	7.1%
	Feedback	Negative	25	32	-0.6%	-4.4%
		Positive	33	40	-1.0%	-6.4%

Category	Code	Attribute	New Map Round 1	New Map Round 2	Relative difference between rounds	Relative difference within category
Image	Goal/vision	Explicit	35	38	-1.3%	-8.1%
		Individual	13	77	3.7%	15.4%
	Satisfaction	Negative	24	55	1.0%	2.9%
		Positive	35	52	-0.4%	-4.0%
Interaction	Bottom-up	Interference	8	12	-0.1%	1.4%
		Interplay	30	45	-0.3%	5.2%
		Intervention	2	0	-0.2%	-2.8%
	Top-down	Interference	1	2	0.0%	0.7%
		Interplay	16	32	0.4%	11.1%
		Intervention	15	5	-1.3%	-15.6%
Instrument	Detector	Information	7	21	0.6%	9.0%
		Organisation	1	34	2.2%	23.6%
		Rule	1	0	-0.1%	-0.9%
	Effector	Information	34	44	-0.8%	1.8%
		Organisation	63	35	-4.6%	-30.1%
		Rule	8	5	-0.5%	-3.4%
SDI qualities	Data provision	Bad	4	22	1.0%	12.1%
		Good	32	22	-2.1%	-10.3%
	Data quality/availability	Bad	12	20	0.0%	4.3%
		Good	29	15	-2.2%	-12.8%
	Use	Non use	1	16	1.0%	10.3%
		Use	47	49	-1.9%	-3.6%
Structures	Roles and responsibilities	Enabling	30	31	-1.2%	-3.7%
		Constraining	13	32	0.7%	1.7%
	Budget resources	Enabling	25	22	-1.3%	-3.8%
		Constraining	29	18	-2.0%	-5.7%
	Culture	Enabling	1	3	0.1%	0.2%
		Constraining	1	7	0.4%	0.9%
	Knowledge resources	Enabling	15	15	-0.6%	-2.0%
		Constraining	3	6	0.1%	0.1%
	Law	Enabling	4	4	-0.2%	-0.5%
		Constraining	10	15	-0.1%	-0.4%

Category	Code	Attribute	New Map Round 1	New Map Round 2	Relative difference between rounds	Relative difference within category
Structures	Ownership	Enabling	11	4	-0.9%	-2.7%
		Constraining	3	15	0.7%	1.7%
	Political capital	Enabling	9	11	-0.3%	-0.8%
		Constraining	4	15	0.6%	1.4%
	Social capital	Enabling	5	30	1.5%	3.8%
		Constraining	0	3	0.2%	0.5%
	Standards	Enabling	31	22	-1.9%	-5.6%
		Constraining	14	35	0.8%	1.9%
	Support	Enabling	27	69	1.7%	3.9%
		Constraining	16	63	2.5%	6.2%
	Technology	Enabling	38	39	-1.6%	-4.8%
		Constraining	9	20	0.4%	0.8%
	Time resources	Enabling	8	20	0.5%	1.1%
		Constraining	15	28	0.2%	0.3%
	Trust	Enabling	1	7	0.4%	0.9%
		Constraining	3	30	1.7%	4.4%
Total			907	1489		

Appendix C. Results and questions Expert Validation

Results and questions of the expert validation to the agent-based model of chapter 4.

Questions 1, 4, 5 and 6 used a Likert scale answers as follow: 1 = Strongly Disagree, 2 = Disagree, 3 = Neither agree/disagree, 4 = Agree, 5 = Strongly agree. Questions 2 and 3 used the following Likert scale answers: 1 = Very unrealistic, 2 = Unrealistic, 3 = Not realistic/unrealistic, 4 = Realistic, 5 = Very realistic. Questions and answers are translated from Dutch.

	1	2	3	4	5	Avg.	N=
1. The actor roles in the model are also the predominant roles you find in a real SDI	0	0	3	11	3	4.00	17
Do you think the behaviour of the following actor roles corresponds with reality?							
2a. SDI Executive	2	3	3	8	2	3.28	18
2b. SDI Data Provider	1	0	9	5	3	3.50	18
2c. SDI Platform Provider	1	0	6	9	2	3.61	18
2d. SDI User	1	1	10	3	3	3.33	18
Do you think that interactions in the model correspond with interactions in reality?							
3a. Interactions between actors in the model (sending messages and feedback)	1	2	7	7	1	3.28	18
3b. Interactions between actors and budget (allocating and spending budget)	1	5	8	4	0	2.83	18
3c. Interactions between actors and the SDI (costs/benefits of SDI)	1	3	8	5	1	3.11	18
Evaluation on results of the governance style scenarios							
4a. The outcomes of the governance style scenarios are credible	1	1	3	11	2	3.67	18

	1	2	3	4	5	Avg.	N=
4b. The outcomes of the governance style scenarios provide more insight in SDI governance.	1	1	3	12	1	3.61	18
Evaluation on the results of the budget policy scenarios							
5a. The outcomes of the budget policy scenarios are credible	0	5	3	7	3	3.44	18
5b. The outcomes of the budget policy scenarios provide more insight in SDI governance	0	4	2	9	3	3.61	18
6 Considering all aspects, this model is useful for gaining more insight in SDI governance	0	2	3	11	2	3.72	18

Appendix D. Overview, Design Concepts, Details (ODD) – SDI Governance Model

This model description follows the ODD (Overview, Design concepts, Details) protocol for describing individual- and agent-based models (Grimm et al. 2006; Grimm et al. 2010). This ODD accompanies chapters 4 and 5. As some modifications were necessary to make the model better fit the context of INSPIRE in chapter 5, these modifications are introduced as: *Modification for the INSPIRE model*.

1. Purpose

The purpose of Spatial data infrastructure (SDI) governance model is to provoke discussion among SDI governors by simplifying and simulating SDI governance. It contains three important governance processes: interactions between actors, interactions between actors and resources and interactions between actors and the SDI. These governance processes are simulated in an agent-based model. The purpose is not to predict SDI governance or to imply all factors which influence SDI governance, but to better understand SDI governance and to gain insight for actions for proper steering of SDI governance in the future.

2. Entities, state variables, and scales

There are four actors in the model, each with specific properties and different roles. The actor's roles represent the (group of) organisations involved in the process of SDI governance and should be seen as aggregations for the actor group they represent. The four actor roles are:

1. SDI executive: this actor role represents the executive branch of government that has authority and responsibility for the SDI. In many cases, the SDI executive has the role of 'policy maker' or coordinator, and determines the mission and vision of the SDI. The SDI executive is in many cases the most influential actor in SDI governance (see e.g. Coetzee et al. 2018; Coetzee et al. 2019).
2. SDI Data Providers: This actor role represents the organisation(s) who delivers spatial data to the SDI. It can also be seen as data producer.
3. SDI Platform Provider: This actor role represents the organisation(s) who maintains and updates the infrastructure and plays a central role in bridging data from SDI data providers to SDI users. It can have the role of provider or broker.

4. SDI users: This actor role represents the organisations(s) who uses the spatial data from the SDI. SDI users use spatial data as end-user or as value added re-seller.

All actors own two main attributes which will change over time: satisfaction and resources (budget). Both budget and satisfaction range from 0 to 10, where 0 means 'not satisfied at all' or 'no resources at all' and 10 means 'very satisfied' or 'a lot of resources'.

The satisfaction represents the satisfaction of the actor with the SDI and its governance in a broad sense. When all actors are dissatisfied (their mean satisfaction is below 1), the model will stop running. When the amount of budget of the SDI executive increases its satisfaction will also increase and vice versa.

The SDI Data Provider and SDI platform provider will spend their resources to maintain the SDI which is represented by a data quality flow. This data quality flow also uses a 0 to 10 scale, representing the availability and quality of spatial data through the SDI. The value of 0 represents no data available or at a very poor quality, the value of 10 represents high quality/availability of data.

The allocation of budget to the SDI data provider and SDI platform provider has been defined with four different scenarios: 1) piecemeal funding in which the budget is allocated project-based (every 5 time steps) by the SDI executive; 2) continuous funding in which there is a steady and stable budget allocation by the SDI executive; 3) pay-per-use funding in which SDI-user will pay the SDI data provider and SDI provider provided that the quality of used data is good and acceptable; 4) *Modification for the INSPIRE model*: INSPIRE financing in which the SDI data provider and SDI platform provider cover their own costs for the SDI until they cannot afford it anymore. When the data quality decreases, they gain extra resources so they can spend it again on the SDI.

There is no spatial scale in SDI governance model. SDI governance can be evaluated within different temporal scales (e.g. daily, monthly and yearly scales). The ticks (time steps) resemble the development of the model over time and its relation with real time is not specific. Thus, ticks should not interpreted in temporal scale of weeks or months but results should be assessed relatively.

3. Process overview and scheduling

At every time step, the following flow is followed subsequently:

Actor interactions

First the type of message (hierarchy, network or no message) is determined. Every message has an equal 1/3 chance of being selected. However, depending on input sliders set by the observer, the chance on a certain message can be affected. When a message is selected a random number is created which will be compared with the setting of the input slider for this message type. When the random number is higher than the setting of the slider, the procedure is started over. When the random number is lower, the sender of the message is selected.

Modification for the INSPIRE model: It is possible for the observer to change this fixed mode to adaptive mode. In adaptive mode, the input sliders which influence the chance on a message can be automatically adjusted. It works as follow: After 15 ticks the average satisfaction of actors is evaluated. If it is higher than 7.5, the settings remain the same. If it is lower than 7.5, the distribution of sent message types is compared. For example, if the amount of sent hierarchy messages is higher than the amount of sent network messages, the slider which influences the chance on hierarchy messages is set -10. If the amount of hierarchy messages is also higher than the amount of no messages, again the slider is set -10. However, if the amount of hierarchy messages is lower than the amount of network messages, the slider is set +10. The same mechanisms apply to the other type of messages. In order to prevent a message type to become overly dominant or underrepresented, two boundary conditions are set: if the chance on a message type goes over a setting of 80, the setting is set back -20. If a setting goes under the 20, the setting is set +20.

If the selected message is a hierarchy message, then the SDI executive is selected as message sender. Else (the selected message is a network or no-message), one of the four actors is selected randomly and determined as message sender.

Then the receiver of the message is selected. This is done by selecting a random actor which is not the sender of the message. The message receiver is also called the feedback sender.

Before the message is send, the actor checks its budget. If it is budget = 0, the

actor will override the message with a no message.

Then the message is (visually) send to the selected receiver.

The actor who receives the message will assess it:

- If the message is a hierarchy message and the previous received message is also a hierarchy message, the satisfaction of the receiver is set -2 and its feedback is set to -0.5. Else, the satisfaction of the actor is set to +2 and the feedback is set to +0.5.
- If the message is a network message and the previous and before previous message were also network messages, the satisfaction of the receiver is set to -2 and its feedback is set to -0.5. Else, the satisfaction is set to +1 and its feedback to +0.5.
- If the message is a no message and the previous and before previous message were also no messages, the satisfaction of the receiver is set to -2 and its feedback is set to -0.5. Else, there is no change in the satisfaction or the feedback of this receiver.

Then the receiver will remember the message and store the previous message (message-1) as before previous message (message-2). The actually received message will be stored as previous message (message-1).

If the satisfaction of message receiver is greater than 5, +1 is added to the feedback. If the satisfaction of the message receiver is smaller than 5, -1 is added to the feedback. If the satisfaction of the message receiver equals 5, then the content is not effected (feedback = 0).

Together with the feedback based on the received message, the total feedback is send to the message sender. If this feedback affects the message sender is dependent on the 'susceptibility to feedback' input slider. With this slider, the chance of feedback getting to the message sender can influenced on a 0 to 100% scale.

Budget interactions

At every time step, budget interactions also occur. The SDI executive gains budget based on the selected budget scenario. In the model there are four budget scenarios: piecemeal funding, continuous funding, pay-per-use funding and *modification for the INSPIRE model*: INSPIRE financing.

- **Piecemeal funding:** With piecemeal funding, budget is provided without a coherent long term vision or strategy, for example by projects. This funding is implemented in the model as such in every 5 ticks 2.5 amount of money goes to the SDI executive. Every time step, the SDI executive allocates 0.25 to the SDI data provider and 0.25 to the SDI platform provider.
- **Continuous funding:** With continuous funding, there is a stable flow of budget covering the main costs of the SDI. In this type of funding, in every tick 0.5 amount of money is sent to the SDI executive. Every time step, the SDI executive allocates 0.25 to the SDI data provider and 0.25 to the SDI platform provider.
- **Pay-per-use funding:** In this scenario, not the SDI executive but the SDI users will recover the costs of the SDI data provider and SDI platform provider by paying for the data if the quality is good enough (data quality > 5). In this model, budget is divided from the SDI user to the SDI platform provider (0.25) and the SDI data provider (0.25) if the data quality is greater than 5.
- **Modification for the INSPIRE model:** INSPIRE financing: In this policy, the SDI data and SDI platform provider pay the maintenance costs until they cannot afford this anymore (budget is < 0.25). If the data quality is still good according to the data user, this situation remains. However, when they get negative data feedback (feedback-data) from the user, they will invest extra to improve the data quality. When their budget hits 0, they gain +3 budget to make these investments.

The amount of budget of the SDI executive also affects his satisfaction. If the amount of budget is higher than 6, his satisfaction increases + 0.5. If the amount is between 3 and 6, his satisfaction is not affected. If it is below 3, satisfaction is decreased with - 1. Other actors are not affected by the amount of budget they possess.

Data interactions

Then the model enters the phase of data dissemination. The SDI data provider and SDI platform provider send data to the SDI user.

- If the satisfaction of SDI data provider is greater than 5, then quality of data is increased by 0.5.
- If satisfaction of SDI data provider and SDI platform provider is smaller

than 5, then data quality decreases by 0.5.

- If satisfaction of SDI data provider and SDI platform provider is equal 5, then data quality will not change.

The same mechanism applies to the SDI platform provider, increasing or decreasing the total data quality.

The SDI user will send feedback to the SDI data provider and SDI platform provider based on the data quality. This is separate stream of feedback, called feedback-data. If the data quality is greater than 5, positive feedback is sent (+1). If data quality is smaller than 5, negative feedback is sent (-1). If data quality is equal 5, then the feedback equals 0 and no feedback is sent.

The SDI data provider and SDI platform provider have to spend budget to maintain the data quality. If they have enough budget (> 0.2 ; *Modification for the INSPIRE model: > 0.25*), they pay 0.25 each. Else, the data quality diminishes by -0.25 per actor.

When the data feedback is negative, the SDI data provider and SDI platform provider can improve the quality of data if they have enough budget. In the model, if the data feedback is negative (< 0) and SDI data provider and SDI platform provider both have more than 0.2 budget, then they both allocate 0.25 of money and the data quality increases by 0.5. If one of the actors has less budget than 0.2, than the other actor allocates 0.5 budget and increases the data quality by 0.5. If both actors have less budget than 0.2, the data quality decreases with -1.

In case of good quality of data, SDI user will increase its budget and satisfaction. If the data quality is greater than 5 than the SDI user will gain 0.5 budget. If the data quality greater than 8, the satisfaction of the SDI user increases by 1.5 in the model. If the data quality is between the range of 5 to 8, then the satisfaction of SDI user increases by 1. If the data quality equals 5, this will not influence the satisfaction of SDI user. If the data quality is between the range of 5 to 3, then the satisfaction of the SDI user decreases by -1. If the data quality is between the range of 2 and 0 will decrease the satisfaction of SDI user by -1.5. And if the data quality equals 0 then satisfaction of SDI user will decreases by -2.

To end the time step, a time penalty is set where the satisfaction of all actors decreases with 0.2 at the end of each time step.

4. Design concepts

Basic principles

The idea to design the model was taken from the signalling game modelling approach (reference: Netlogo library). In this approach, the involved actors communicate with each other in order to understand their current state of environment. In the context of SDI governance, the four actors (SDI executive, SDI provider, SDI data provider and SDI user) interact in order to achieve a successful governance of the SDI system. The model was initiated with the two actors of SDI executive and SDI user and later on, more complexity was introduced including SDI platform provider and SDI data provider actors. Later on, the budget interaction and data flow within the SDI system (SDI platform provider, SDI data provider and SDI user) were added, which still can be switched off with a switch. The purpose of the added complexity is to simulate the interactions among the four actor roles involved in the process of SDI governance, while maintaining the SDI system.

Emergence

Based on the inputs set by the observer at the start of the model (chance on hierarchy messages, network messages and no-messages, the susceptibility to feedback and the budget policy) the governance interactions of the actors are influenced. In the model we look at how sustainable these interactions are by looking at the life span of the SDI. As the observer can influence only the chances on interaction types, it is still unpredictable how long the model will run each time. As the interactions are based on the inputs (i.e. the actors cannot adapt by applying a different interaction strategy) all models will fail inevitably.

Adaptation

The original modus of the model contains little adaptive behaviour. The actors do not change their strategies depending on the state of the system. The strategies are based on chances and input settings of these chances by the observer.

An exception is the data flow. In order to keep a reasonable flow of data (data availability and high quality) within SDI system, a kind of adaptive behaviour has been implemented in the model. The SDI user will send negative feedbacks in case of a poor data flow (data flow < 5). To improve the flow of data, the SDI platform provider and SDI data provider spend 0.5 budget (0.25 per each actor) and the data quality increases with 0.5. If SDI platform provider or SDI data

provider do not have any budget, the one that has budget spend the full 0.5 budget to improve the data quality. These costs come above the normal costs for maintaining the SDI.

Modification for the INSPIRE model: When the model is put in adaptive mode, the dynamics of the simulation may be adaptively influenced after a period of 15 ticks. If then the average satisfaction is less than 7.5, the chances on a certain message are automatically influenced, based on the distribution of sent messages. If one message type was overrepresented, the chances on this message type are lowered. The chance on an underrepresented message type are increased. In this way, the model dynamics try to adjust the governance mix in order to become more sustainable.

Interaction

There is direct interactions among SDI executive, SDI platform provider, SDI data provider and SDI user. The direct interactions consist of sending hierarchy, network and no messages and receiving feedback. These interactions are represented as sets of links in the model among the different actors. There is also another set of indirect interaction in which the data flows from the SDI platform provider and SDI data provider to the SDI user. The SDI user responds with direct feedback to this. The communications in this interaction are also represented with sets of links. The last form of interaction is between the actor and its budget. As some actors will give budget (depending on the budget policy) and others spend budget, the spending actors are dependent on a source of income from these other actors.

Stochasticity

In the SDI governance model, there are three processes in which random selection are implemented. First, a random process of selecting a hierarchy, network or no message occurs of which the chances can be influenced by sliders. Second, one actor among four actors to send the message is selected. The third random process is the selection of an actor to receive the randomly selected message. Also the susceptibility of feedback can be changed, which changes the chance the actor will listen to the feedback and change its satisfaction. As this are the main principles of the model, running the model shows a lot of stochastic behaviour.

Observation

The graphic user interface provides several types of graphs and monitors in order to follow the dynamics of the model. The graphs provide visual interpretation of variables such as: 1) satisfaction of SDI executive, SDI platform provider, SDI data provider, SDI user and also their overall (mean) satisfaction; 2) data quality over time, and 3) budget of SDI executive, SDI platform provider, SDI data provider and SDI user. Monitors provide information about the number of a certain type of selected message. The model stops running if the mean satisfaction of the actors equals 1 or less. This output (the amount of time steps the run took before it failed) is also collected.

5. Initialisation

At initialisation all data from previous runs is deleted, the time is reset and the four actors are created. The messages and the previous message (message-1) and before previous message (message-2) are set to the neutral 'not yet messaging'. The global and actors own-variables such as data quality, satisfaction and budget are set by default to 5. This setting is fixed on initialisation to make outcomes in the dynamics of the model better comparable. However, these values can be easily changed in the code if necessary. These initial values were chosen as they are the middle values of their range.

Before running the model, the observer can modify four sliders and one chooser:

- Slider to determine the chances on hierarchy messages (0 to 100)
- Slider to determine the chances on network messages (0 to 100)
- Slider to determine the chances on no messages (0 to 100)
- Slider to determine the susceptibility to feedback (0 to 100)
- *Modification for the INSPIRE model*: Button for switching adaptive mode on or off
- Chooser for determining the budget policy:
 - a. Piecemeal funding
 - b. Continuous funding
 - c. Pay per use funding
 - d. *Modification for the INSPIRE model*: INSPIRE financing

6. Input data

External sources were not used to develop the SDI governance model.

7. Submodels

There are no sub models used in this agent-based model. All processes are mentioned in the 'process overview and scheduling'.

Appendix E. Blank governing system framework for application in practice

Summary

To facilitate spatial data sharing and exchange, many organisations developed Spatial Data Infrastructures (SDIs). SDIs are becoming nowadays more mature worldwide, but are also challenged by new technologies and user demands. Proper SDI governance seems essential, but it is unclear to what extent current SDI governance is fully equipped to deal with the dynamics and complexity of SDIs. The objective of this research is to analyse SDI governance dynamics and to develop tools in order to gain insights in current SDI governance and their possible future.

First, two longitudinal SDI case studies were conducted about the governance of large-scale base maps in the Netherlands and Flanders (Belgium). Both initiatives represent decades-long undertakings to create a large-scale base map. We found that SDI governance is adaptive, as it changed considerably during the evolution of these two SDIs. In most cases, the governance approaches of these SDIs did not hold up very long, as they were either not meeting their goals, were not satisfying all stakeholders or were not in alignment with new visions and ideas. Recently, the instruments governing these SDIs have become increasingly diverse. We see especially an increase in hierarchical instruments in these two cases. In general, governance scientists agree that by using a broader mix of policy instruments, governance becomes more adaptive.

To gain more insights in SDI governance and the shifts we observed, a framework was developed for evaluating the governing system of SDIs based on the theoretical conceptions of Kooiman (2003). In this framework we distinguish two levels: an actor level, where images are formed, instruments are chosen and applied into action, and a structural level, where the formal and informal structures and resources reside which enable or constrain the actor level. This framework is applied to two Dutch SDI cases: the Risk Map and the New Map of the Netherlands. With the help of the framework, the strong and weak aspects of the governing system of SDIs become apparent and insights emerge on which interactions, images, instruments, actions and structures enable or constrain SDI governance. By observing changes in governing systems over time, dynamics in this system become visible. Therefore, the framework is an useful analytical tool for gaining more insights in SDI governance and its dynamics.

Another tool this research developed is an agent-based model for simulating

SDI governance interactions. Agent-based modelling is a suitable method for understanding complex emergent behaviour of a system by modelling local interactions of actors. In this agent-based simulation, we examined interactions between SDI stakeholders, data availability, the effects of different governance styles (hierarchical, network and laissez-faire governance) and budget policies. By running different scenarios, it appeared that a network governance approach is more successful compared to a hierarchical or laissez-faire approach. Expert validation showed that overall the results of the simulation are credible and insightful, although improvements can be made to make the model more realistic. With agent-based modelling, SDI governance becomes more tangible and visible. Therefore, it is a helpful tool in facilitating discussion and understanding of SDI governance and their dynamics.

Both tools, the agent-based model and the governing system framework, were applied to INSPIRE, the European Spatial Data Infrastructure. INSPIRE is an initiative which enforces European Union (EU) member states to harmonise data on specified themes and provide this data through network services from their national SDI. By using an online survey, the main stakeholders of INSPIRE provided input to evaluate INSPIRE's governing system. Furthermore, this input is applied in the agent-based model to project future and alternative governance scenarios. The results from the survey show that strong aspects of INSPIRE's governing system are the supported vision and its formal structures such as standards, technology and roles and responsibilities. Weak aspects are its data use and the access to resources, especially budget and time resources. Simulations ran with the agent-based model also indicate that the current budget policy is constraining INSPIRE's governance for the future.

This research analysed the SDI governance dynamics of several cases. Based on these cases, it is clear that there is no golden recipe for SDI governance. Even if the results are very similar which is in the case of the large-scale base maps, governance trajectories of SDIs can be very different and change over time. Although SDI governance is already adaptive, SDI governance in general may anticipate better on these dynamics in order to improve its adaptive capacity and prevent governance crisis situations. For example, by allowing a mix of self-organising, network and hierarchical governance forms and regularly reviewing the governing system to ensure it is enabling.

With the help of the developed tools, the SDI governing system framework and

agent-based model, it is possible to get a better understanding of what enables and constrains the dynamic governance processes of SDIs. With the agent-based model, even possible governance futures can be explored. These tools help to provide more insights in the strong and weak aspects of the governance of an particular SDI. It is important to discuss the outcomes from these tools in order to facilitate learning and discussion among SDI practitioners. In this way, SDI governance may become both more flexible and adaptive, while also improving the robustness of its system for unexpected developments.

Samenvatting

Om het delen en uitwisselen van ruimtelijke data te faciliteren, hebben veel organisaties ruimtelijke data infrastructuren (SDI's) ontwikkeld. SDI's zijn tegenwoordig steeds volwassener, maar worden ook onder druk gezet door nieuwe technologieën en gebruikerswensen. Goede SDI governance lijkt hierom essentieel, maar het is onduidelijk in welke mate de huidige governance van SDI's kan omgaan met de dynamiek en complexiteit van SDI's. Het doel van dit onderzoek is om de SDI governance dynamiek te analyseren en om instrumenten te ontwikkelen die inzicht kunnen verschaffen in de huidige en mogelijk toekomstige governance van SDI's.

Eerst wordt de governance van twee langjarige SDI casussen onderzocht, namelijk de grootschalige basiskaarten van Nederland en Vlaanderen (België). Beide SDI's zijn decennia oude trajecten om een grootschalige basiskaart te ontwikkelen. We ontdekten dat SDI governance zich adaptief gedraagt, aangezien de governance aanzienlijk veranderde gedurende de evolutie van deze twee SDI's. De governance aanpak van deze SDI's hield vaak niet heel lang stand, omdat óf de doelen niet gehaald werden, óf de belanghebbenden niet tevreden waren óf ze waren niet in lijn met nieuwe visies en ideeën. Recentelijk zijn de besturingsinstrumenten voor deze SDI's steeds diverser geworden. We zien vooral een toename in de hiërarchische instrumenten bij deze twee casussen. Over het algemeen wordt in de bestuurswetenschap onderschreven dat door de toepassing van een bredere mix van beleidsinstrumenten, governance adaptiever wordt.

Om meer inzicht te verkrijgen in SDI governance en de verschuivingen die we hierin hebben waargenomen, is een raamwerk ontwikkeld om het governance systeem van SDI's te evalueren gebaseerd op de theoretische concepten van Kooiman (2003). In dit raamwerk onderscheiden we twee niveaus: een actor niveau, waar beeldvorming plaatsvindt, instrumenten gekozen worden en in de praktijk worden toegepast, en een structureel niveau, waar middelen, formele en informele structuren zich bevinden die het actor niveau kunnen faciliteren of belemmeren. Dit raamwerk is toegepast op twee Nederlandse SDI's: de Riscokaart en de Nieuwe Kaart van Nederland. Met behulp van dit raamwerk komen de sterke en zwakke aspecten in het governance systeem van een SDI aan het licht en wordt er inzicht verschaft in hoeverre de interacties, beelden, instrumenten, acties en structuren de SDI governance faciliteren of beperken.

Door veranderingen in governance systemen door de tijd te observeren, wordt de dynamiek in dit systeem zichtbaar. Het raamwerk is daarom een nuttig instrument om SDI governance te analyseren en meer inzicht in haar dynamiek te verkrijgen.

Een ander door dit onderzoek ontwikkeld instrument is een agent-gebaseerd model om SDI governance interacties te simuleren. Agent-gebaseerd modelleren is een geschikte methode om complexiteit en emergentie van een systeem te doorgronden door lokale interacties van actoren te modelleren. In dit agent-gebaseerde model onderzoeken we de interacties tussen SDI stakeholders, de beschikbaarheid van data, de effecten van verschillen besturingsstijlen (hiërarchisch, netwerk en laissez-faire governance) en financieringsbeleid. Door verschillende scenario's te simuleren, bleek een netwerk governance aanpak het meest succesvol vergeleken met een hiërarchische of laissez-faire aanpak. De validatie met experts toonde aan dat de resultaten van de simulaties over het algemeen geloofwaardig waren en inzicht boden, hoewel verbeteringen aangebracht kunnen worden om het model realistischer te maken. SDI governance wordt met behulp van agent-gebaseerde modellen zichtbaarder en tastbaarder. Het is daarom een nuttig instrument om discussies op gang te brengen en een beter begrip te krijgen in de dynamiek van SDI governance.

Beide instrumenten, het agent-gebaseerde model en het raamwerk om governance systemen te analyseren, werden toegepast op INSPIRE, de Europese ruimtelijke data infrastructuur. INSPIRE is een initiatief dat lidstaten van de Europese Unie (EU) verplicht om data op specifieke thema's te harmoniseren en te verstrekken via netwerkservices vanuit hun eigen nationale ruimtelijke data infrastructuur. Met behulp van een online enquête hebben de belangrijkste stakeholders input gegeven om INSPIRE's governance systeem te evalueren. Deze input is daarnaast gebruikt in het agent-gebaseerde model om toekomstige en alternatieve scenario's te simuleren. De resultaten uit de enquête tonen dat de sterke aspecten van INSPIRE's governance systeem liggen in de gesteunde visie en de formele structuren zoals de standaarden, technologie en de belegde rollen en verantwoordelijkheden. Zwakke aspecten zijn het gebruik van data en de toegang tot middelen, vooral budgettaire middelen en tijd. Ook de simulaties met het agent-gebaseerde model geven aan dat het huidige financieringsbeleid de toekomst van INSPIRE's governance belemmert.

Dit onderzoek analyseerde de SDI governance dynamiek van verschillende

casussen. Gebaseerd op deze casussen is het duidelijk dat er geen gouden recept voor SDI governance is. Zelfs als de resultaten erg op elkaar lijken zoals in het geval van de grootschalige basiskaarten, kunnen de governance trajecten van SDI's erg verschillen en veranderen door de tijd. Hoewel SDI governance al adaptief is, kan SDI governance over het algemeen beter anticiperen op deze dynamiek om zo het aanpassingsvermogen te versterken en governance crisissituaties te voorkomen. Dit kan door bijvoorbeeld een bredere mix van zelforganiserende, netwerk en hiërarchische governance vormen te gebruiken en regelmatig het governance systeem tegen het licht te houden om ervoor te zorgen dat het de governance faciliteert.

Met behulp van de ontwikkelde instrumenten, het raamwerk voor SDI governance systemen en het agent-gebaseerde model, is het mogelijk om beter te begrijpen wat het adaptieve governance proces faciliteert en beperkt. Met het agent-gebaseerde model kunnen zelfs mogelijke "governance toekomst" worden verkend. Deze instrumenten zorgen voor meer inzicht in de sterke en zwakke aspecten van de governance van een SDI. Het is belangrijk om de uitkomsten van deze instrumenten te bespreken met SDI stakeholders om zo leerprocessen en discussie op gang te helpen. Op deze manier kan SDI governance flexibeler en adaptiever worden, terwijl ook de robuustheid van het systeem voor onverwachte ontwikkelingen wordt verbeterd.

Acknowledgements

Like a spatial data infrastructure (SDI), also a PhD candidate will not prosper without an enabling 'governing system' surrounding it. Luckily, I was in the possession of a very enabling system, although a few constraining factors existed. Let's analyse this system!

Also a PhD research starts with a perceived problem, an 'image'. During my time working at the Ministry of Infrastructure and Environment I noticed that SDI governance was certainly a challenging subject. When Arnold called if I was interested in joining a research project studying the governance of spatial data infrastructures my interest was certainly raised. By continuing working at the Ministry and the Dutch Cadastre (Kadaster) while performing this research, it enabled me to look at practice through an analytical governance lens and keep the research useful for practice.

However, especially helpful in the latter case, was the 'GOV4SDI' user committee. This team of experts from industry and government was always ready to provide me with valuable feedback and new ideas and directions. The useful discussions we had always provided me with a lot of energy to continue and improve the research. Dirk van Barneveld (Ministerie van Binnenlandse Zaken), Jan Willem van Eck (ESRI), Johan van Arragon (Provincie Zuid-Holland/Geonovum), Martin Salzmann (Kadaster) and Michiel Jellema (Infolio/HAS Hogeschool): Thank you very much for your time and inspiration!

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Because indeed, time was the most constraining resource. Having (formally) only one day in the week available for performing a PhD research is challenging. Luckily, a few factors enabled me to do this. First of all, I have to thank Kadaster for letting me attend courses and conferences in their time. Second, a big thank you goes to Jalal Samia, who helped incredibly with setting up the agent-

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Of course, this is not always fun for your partner. Therefore, I am deeply grateful for the support and patience that Jessy provided. She never complained when I had to work and I am certain that thanks to her love and the fun things we did together, I was able to do this research without mental breakdowns. In this respect I also have to acknowledge our dog, Gaia², which is a great co-worker during lockdowns.

But I also have to thank my family, friends and co-workers at the Kadaster and GRS lab at Wageningen University for their support. They always showed interest in the process and progress, even if I joked around that it was just a 'side job'. A special thanks also go to my peers from the Public Governance Institute in Leuven. As the amount of governance researchers in the GRS lab was low, it was always a delight to travel to Belgium and discuss the issues of researching governance with Maxim Chantillon, Rink Kruk and Stijn Wouters at KU Leuven.

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² The similarity of her name with the 'Gaia' building of Wageningen University is not intentional or at least unconscious. Of course, this building is also appreciated during non-lockdowns.

About the author

Jaap-Willem Sjoukema (1991) was born in Apeldoorn and raised in Woudenberg, the Netherlands. After obtaining his Gymnasium diploma in Amersfoort he moved to Utrecht where he studied Human Geography and Planning at Utrecht University. During this bachelor (BSc) study, he joined study association V.U.G.S. as a full-time board member for a year.

After obtaining his BSc degree he enrolled in the master (MSc) programme Geographical Information Management and Applications (GIMA) in 2013. This is a cooperation of four renowned Dutch universities in the area of geo-information, namely the University of Twente/ITC, TU Delft, Utrecht University and Wageningen University. During his master's thesis he asked whether it is possible to use volunteered geographic information (VGI) for keeping the new key registry large-scale topography (BGT) up-to-date. The answer was positive and he joined the BGT programme office at the Ministry of Infrastructure and Environment as intern to draft the requirements for a crowdsourced feedback system. He obtained his MSc degree cum laude in 2015.

As his work on the feedback system was highly appreciated, Jaap-Willem remained attached to the BGT programme office as advisor after his study. Furthermore, he was appointed at the Dutch Cadastre (Kadaster) as product owner to develop this new feedback system. In May 2016, he started as PhD candidate at Wageningen University to study the governance of spatial data infrastructures (SDIs).

As the feedback system proved to be successful, he left the BGT programme office mid-2017 in order to better focus on expanding and developing this system at the Kadaster to incorporate other key registries. Furthermore, his portfolio expanded to include other generic SDI related services such as map viewers. He continued combining this position of product owner with that of PhD candidate. This combination proved to be valuable to better understand theory and practice, for example during international consulting for the Belarusian spatial data infrastructure. Now with the completion of this thesis, Jaap-Willem will continue his passion to improve governmental geo-information services in the Netherlands and elsewhere.

PE&RC Training and Education Statement

With the training and education activities listed below the PhD candidate has complied with the 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 (6 ECTS)

- The governability of spatial data infrastructures

Post-graduate courses (4 ECTS)

- Network governance: theories, methods and practices; Netherlands Institute for Government (2018)

Deficiency, refresh, brush-up courses (2.3 ECTS)

- Introduction to agent based modelling; Santa Fe Institute (2020)

Competence strengthening / skills courses (2.2 ECTS)

- PhD Competence assessment; WUR (2016)
- Brain-friendly working and writing; WUR (2019)
- Scientific integrity; WUR (2019)
- Brain training; WUR (2020)
- Research integrity; KU Leuven (2021)
- Adobe InDesign; WUR (2021)

PE&RC Annual meetings, seminars and the PE&RC weekend (1.5 ECTS)

- PE&RC First years weekend (2016)
- PE&RC Last years weekend (2020)

Discussion groups / local seminars or scientific meetings (5.1 ECTS)

- GOV4SDI user committee; WUR (2016-2021)
- 2nd Crowdsourcing and national mapping workshop, KU Leuven (2017)
- SDI Research and strategies towards 2030, University Lund; Sweden (2018)

- NCG Conference; WUR (2018)
- PhD Discussion meetings; KU Leuven (2016-2020)
- Knowledge graphs in action; SEMANTICS (2020)
- NCG Conference; NCG (2020)
- iBestuur debat: de nieuwe data-beleidscyclus; iBestuur (2021)

International symposia, workshops and conferences (11 ECTS)

- FOSS4G; Bonn, Germany (2016)
- Geobuzz; Den Bosch, the Netherlands (2016)
- GSIDI; Taipei, Taiwan (2016)
- BeGeo; Brussel, Belgium (2017)
- INSPIRE; Strasbourg - Kehl, France - Germany (2017)
- INSPIRE; Antwerp, Belgium (2018)

Lecturing / supervision of practicals / tutorials (4.2 ECTS)

- SDI- GRS (2017)
- GIMA Module 3 (2018-2021)

MSc thesis supervision (3 ECTS)

- Towards a sustainable demand-driven provincial organizational structure with regard to geographical information

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