

Challenges in Spatial Data Infrastructure research: a role for transdisciplinarity?

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Abstract

The field of Spatial Data Infrastructure (SDI) is developing and approaches rapidly a “critical mass” of more or less operational SDIs. The purpose of the paper is to anticipate the possible impact of the maturing SDI field on its research agenda. Initial initiatives were predominantly techno centred whereas present initiatives are generally placed within current practices and developments in the exchange of spatial data between multitudes of diverse societal stakeholders. But the nature of the SDI concept is changing as well. Recent trends suggest the inclusion of data collection when needed (geo-sensors) without necessarily storing the ad-hoc collected data after use. Moreover, SDI may gradually lose its distinctiveness and become part of general information infrastructures (e.g. e-government). Once operational, SDIs need assured (self) sustainability and continuous development. Different challenges and dilemmas will also be met. The many possible data sources bring the need to choose; the initial scarcity of available data is traded for the scarcity in the ability to select. Similarly, the ability to communicate with more-and-more people (network externalities) brings diverse and often mutually conflicting worldviews and perceptions of reality. The paper first explores this maturing SDI concept as socio-technical and multi-faceted assembly, and the approaches for assessment and support of concrete SDI initiatives respectively. Future research on SDI initiatives has to address a variety of dilemmas like long-term versus short-term influences, generalization versus the ad-hoc and particular, standardization versus multiple perspectives of reality. Additionally, as SDIs become more mature and institutionalized an increase in demand for research and application of SDI monitoring and evaluation methods can be expected. It seems that contemporary GIScience is predominantly techno centred finding it difficult to accommodate the apparently reflective and socio-technical research that is needed to effectively contribute to SDI development. The paper argues that socio-technical research in this field has to deal with the dilemmas that come with developing and maturing SDI. And will employ a variety of methods as, for example, ethnography, surveys, experiments, life histories, comparative research, and historical analysis. Genuinely socio-technical SDI research is transdisciplinary and draws the realities and rationalities of the concrete SDI case into the research and therefore broadens the scope of contemporary, disciplinary SDI research. Finally, the paper suggests some challenges and consequences this might bring for contemporary GIScience praxis; specifically for its organization and researchers.

Keywords: SDI research, transdisciplinary, socio-technical, future trends

INTRODUCTION

This paper is about the change in research orientation that will be needed for understanding the developing and maturing field of Spatial Data Infrastructure (SDI) and for effectively contributing to it. Initial SDI initiatives were mostly about designing predominantly technical possibilities and artefacts. These had to be adapted to the anticipated user community and the users had to change in order to make the most

of the artefact (see also Dahlbom et al. 1993: 74). Contemporary initiatives, however, must acknowledge existing practices and developments in the exchange of spatial data between multitudes of diverse societal stakeholders. Moreover, the SDI field also develops in that implementation and operational issues have emerged in addition to the design of anticipated SDI initiatives. In other words, the SDI diffusion process is rapidly approaching a “critical mass” of more or less operational SDIs; if it does not have so already (see also Rogers 1993). The paper argues that research on this maturing SDI field needs a genuine socio-technical and praxis-focused research paradigm. Hence, the paper also explores some possible challenges this might bring to the SDI research communities; specifically the academe.

The proliferation worldwide of the SDI idea over the last two decades is reflected by a markedly growth of professional and scholarly activities. [Indication of these developments are for example the volumes by Groot and McLaughlin (2000), Williamson et al. (2003), Masser (2005), and Onsrud (2007) as well as to the Global Spatial Data Infrastructure Association (www.gsdi.org), the so-called SDI Cookbook (Nebert 2004) and the International Journal of Spatial Data Infrastructures Research (<http://ijmdir.jrc.ec.europa.eu>).] Its practical and operational implementation in concrete cases, however, appears unruly and sometimes even problematic. For example, Cromptvoets et al. (2004: 665, 687) observe a declining trend in the use, management and content of national clearinghouses – one of the main elements of SDI facilitating access and providing complementary services. The implementation clearinghouses appears to be a complex task, fraught with difficulties, in sustaining a shared language, a shared sense of purpose, and reliable financing (Cromptvoets et al. 2008b). Craglia et al. (2008: 149) observe that in spite of a greater emphasis on interoperability through services, the underlying basic approach to an SDI architecture has not evolved much during the last ten years. Masser (2005: 258-261) suspects some element of wishful thinking in many of the countries’ claims of being involved in some form of SDI development. He also points at some overly optimistic rhetoric and stresses the need to rigorously examine claims that SDI will promote economic growth, better government, and improved environmental sustainability; more attention should be given to possible negative impacts (see also Craglia 2006: 3).

Against this socio-technical backdrop of the evolving SDI field, the question arises how far geographic information science (GIScience) can support the praxis-focused discourse that comes with it. Mark (2000: 48) defines GIScience as “the basic research field that seeks to redefine geographic concepts and their use in the context of geographic information systems”. Addressing the question of its relevance, Georgiadou and Blakemore (2006) found in their survey on mainstream GI journals that the majority of current research in GIScience is characterized by a strong technical orientation and positivist paradigm with expectations of technical benefits overwhelmingly dominating reflexivity and critique. Current (SDI) research tends to be inward oriented, failing to reach out to other disciplines and their theories, concepts, and frameworks (e.g. Budhathoki et al. 2007: 12; De Man 2007: 6). It seems that contemporary GIScience finds it difficult to accommodate the apparently reflective and socio-technical research that is needed to effectively contribute to SDI development (see also Craglia 2006: 8). The paper argues that genuine socio-technical research in this field has to be inter- and even transdisciplinary rather than mono- or multi-disciplinary and deal with the dilemmas that come with developing and maturing SDI.

The remainder of the paper first elaborates on the maturing SDI concept as socio-technical and multi-faceted assembly, and on the approaches for assessment and support of concrete SDI initiatives respectively. Then the research paradigm to

accommodate the discourse that is challenged by the evolving SDI field is discussed as well as the contours of the related research. Finally, the concluding section suggests some challenges and consequences this might bring for contemporary GIScience praxis; specifically for its organization and researchers.

MATURING SDIS: MULTI-FACETTED AND EVOLVING ACTOR NETWORKS

The SDI concept is challenged by its ambiguity; it is multi-faceted. This implies that different perspectives are possible in understanding the concept and that concrete SDI initiatives can mean quite different things to different people. Moreover, different perspectives may bring conflicts between different requirements, interests and values. Their multi-faceted nature makes SDIs complex beyond technicalities or just being 'difficult'. Complexity is understood here as 'things relate but don't add up' and as 'more than one and less than many' (Mol et al. 2002: 2, 11). Complexity does not necessarily develop into higher-order unity and must be viewed as reciprocal reference of individual actors ([Kwa 2002](#)). Instead of capturing and controlling complexity, the challenge is to acknowledge multiple realities shaped by different and heterogeneous actors ([Hilhorst 2004: 56](#)). Under certain conditions, complexity will increase the reliability of systems under uncertainty – though within certain limits yet ([Carlson et al. 2002: 2539-2540](#)).

SDIs are multi-faceted

The multiplicity of facets that are embodied in the SDI concept can be grouped into three categories regarding to (1) the functionality of SDIs independent of time and place, (2) the specific context for the provision of spatial data and information, and (3) the transformational dynamics or 'beyond SDI' (De Man 2008b: 26, 28-34). Facets that are generally embodied in all concrete instances of SDI include the following. SDIs are about communication and sharing of data and information both within and across different (governance) levels. They are networked infrastructures and would have 'network externalities' where all users benefit when a new user joins the network (e.g. [Monteiro et al. 1995](#); [North 1990: 7](#)) but could also have fragmenting, discriminating, and exclusionary effects (see also [Graham et al. 2001: 11, 33, 219-303](#)). SDIs encompass both technical and social elements and are therefore regarded as socio-technical assemblies (e.g. [De Man 2006](#); [Harvey 2000](#); [Reeve et al. 1999](#)). SDIs are supposed to support a wide group of stakeholders in the communication and sharing of spatial data and can therefore be viewed in terms of a 'commons'. Consequently, they need a broader scope of analysis than narrowly defined economic issues. (See for the relevant paradigm of 'coping with tragedies of the commons' [Ostrom 1990](#); [Ostrom 1999](#); [2000](#); [2005](#)). SDIs generally operate within unstable environments and the ability to adapt may be critical to their success and viability. SDIs therefore can be viewed as self-organising, complex adaptive systems ([Amin 2000](#); [Levin 2002](#)). Like any other technology, SDIs may develop institutional properties in the abilities to communicate, connect, and share between stakeholders once implemented ([Orlikowski 1992: 406](#)). Institutionalization of a concrete SDI initiative can be another condition for its viability and address the problems of obsolescence and irrelevance ([De Man 2006: 338-340](#)).

The context in which an SDI operates and performs is another source of complexity for various reasons. First, handling (spatial) data is problematic. Storing and provision of data inevitably implies selection and revolves around non-trivial questions as which data is kept and what is ignored, and what standards are applied. Essentially, this is a matter of power and domination ("who owns the map legend?"; [Rambaldi 2005](#)). The resulting information is confined to the assumptions and beliefs with which the data were collected and stored. Second, SDI has a potentially harmful

effect under these adverse conditions. Scott (1998: 1-8) argues that modern statecraft relies on simplification by rationalization and standardization – “seeing like a state”. Biases and distortions are potentially dangerous in view of decision making under uncertainty, specifically where “things can go badly wrong”; situations at risk, the normal case in societal decision making. Scott therefore makes a case for the indispensable role of practical (local) knowledge, informal processes, and improvisation in the face of unpredictability (: 6, 307-357). Third, this would necessitate specialized approaches to capture such local, indigenous knowledge adequately. SDI – like any data and communication infrastructure – is therefore not only about situations at risk but its functioning and performance brings risk as well. If SDI is about risk management it must be embedded within the locus of societal risk defusing operators. This is the institutional, organizational and network structure of society for that is the locus of societal risk defusing in the coordination of different views and interests ([Kostov et al. 2003: 469-473](#)). It follows that the SDI initiative would gain an institutional (structural) property within the ‘risk community’ but this will be different at different governance levels (De Man 2008b: 32).

Finally, SDIs and their respective environments are interacting and this mutual dynamism is a source of complexity as well and propels the evolution and maturing of the SDI concept. [This process is akin to Giddens’ notion of ‘structuration’ ([Giddens 1984: 1-40, 376](#)) and the notion of ‘duality of technology’ of Orlikowski (1992: 406): the SDI and its societal environment mutually constitute one another.] Viable SDIs are flexible and able to learn and adapt to (ever-) changing circumstances. [Masser \(2005: 262-263\)](#) distinguishes between the short-term processes needed to initially adapt the notion of an SDI to existing context, and the processes that are involved in its evolution over time in response to changing political, institutional, and technological circumstances. The evolution of the SDI concept can be generational when the concept evolves but not fundamentally or transformational when the concept evolves ‘beyond SDI’. The conceptual evolution from a ‘product-based’ to a ‘process-based’ approach can be seen as an example of generational evolution in SDI development (see also [Rajabifard et al. 2002: 14-17](#)). Transformational dynamics may come in at least three different directions. First, the SDI concept may change from initially being restricted to identification, access, coordination and sharing of spatial data to the inclusion of data collection when needed (geo sensors) without necessarily storing the ad-hoc collected data after use. Second, the SDI concept may lose its distinctiveness and its spatial functionalities become integral part of information infrastructure in general. This trend may be attributed to the apparent convergence of geographic information technology and other ICTs (e.g. [Reeve et al. 1999: 177-185](#)). It may be reinforced by the widespread availability of the internet and the emergence of location-based services (e.g. [Jiang et al. 2004: 89](#)). The third trend in transformational dynamics is when information infrastructures – including SDIs – become an institutional property of the governance system in which they are implicated (De Man 2006; see also Giddens 1984: 1-40; Orlikowski 1992).

SDIs as evolving socio-technical actor networks – a ‘moving target’

SDIs share with other technologies the facet of being socio-technical assemblies. The related question as to whether technology is primarily technical or primarily social has been extensively dealt with in the literature under the rubrics of social construction of technology (e.g. [Bijker 1995; Bijker et al. 1992](#)), science and technology studies (e.g. [Latour et al. 1979](#)), actor-network theory (e.g. [Callon 1980; Callon 1986; Latour 1999; Latour 2005; Law 1992; 2000; 2003](#)), and duality of technology (e.g. [Orlikowski 1992](#)). The actor network perspective views SDIs as emerging from a continuous process of negotiations (‘translations’; [Callon 1986](#)) and

alignments between heterogeneous actors and, hence, as potential unstable (e.g. De Man 2006; Harvey 2001; Martin 2000). Consequently, SDI initiatives will never be finished and therefore resemble a 'moving target'. At the same time, they are never developed from scratch and always be integrated into and thereby extending others - the 'installed base' (Ciborra et al. 1998: 310). Moreover, SDIs – or any other infrastructure for that matter – are more than artefacts. One of the defining properties of infrastructure is its performance. Or, more precisely formulated: its act of performing. As Latour (2005: 154) puts it, "actors have to do something, not to be placeholders". The process of actor-networking brings the initial stage of the SDI initiative towards a stage that is more entrenched in the case-specific and contextual nitty-gritty of what Lindblom (1959) so eloquently referred to as 'muddling through'. (We return to this later in the paper.)

ASSESSMENT AND SUPPORT OF EVOLVING SDIS

SDI evolution influences SDI assessment in two ways: firstly, it has impact on the form of SDI assessment (from intuitive to rational); secondly, it has impact on the concept of SDI assessment (from simplistic to complex assessment frameworks).

As stated by Bregt et al. (2008) a shift can be observed from an intuitive to a rational assessment of SDIs. The first SDIs assessments were done when the knowledge about SDIs was rather limited. The purpose of the assessment was mainly driven by curiosity and aimed at gaining better insight into SDIs. With the evolution of SDIs into more complex but better understood infrastructures, measuring benefits becomes more important (Georgiadou et al., 2006a) and the demand asks for more rational assessment aiming at measuring the accomplishment of SDIs intended objectives. For academia it is a challenge now to follow the changing assessment demands. There is a need to develop scientifically sound and policy relevant assessment approaches which would help SDI policy makers make sure that their SDIs are on the intended track of development and that SDIs provide the intended benefits to the users.

The process of SDIs evolution into more complex and multifaceted phenomena is also reflected in the recent studies on the concept of SDI assessment. In 2009 one of the first projects aiming at building a comprehensive framework to assess SDIs was completed. The project, part of the Dutch innovation program 'Space for Geo-information', acknowledged the complex and multi-disciplinary character of SDIs. It took the scientifically challenging approach to consider all the SDI's components (Rajabifard et al., 2002) and its historical, legal, cultural, technological, institutional and economic contexts (Crompvoets et al., 2008). The main result of the project is a "Multi-view SDI assessment framework". The framework is theoretically based on the assumption that SDI to a certain extent can be considered as a Complex Adaptive System (CAS) (Grus et al., 2008). The result of the project assumes that the main reason for SDI complexity is the human factor. The human factor can be characterized by the variety of expertise, experience, culture and objectives towards SDIs. Those characteristics continuously evolve following and sometimes driving SDI evolution itself. For this reason SDIs with their evolution has become rather complex than complicated phenomena. Therefore simple assessment frameworks aiming at SDI assessment may not be a valid approaches anymore. What is needed is a multi-view approach which acknowledges the interdisciplinary and complex character of SDIs. The Multi-view SDI assessment framework is based on recommendations for assessing complex phenomena. (Eoyang and Berkas, 1998; Cillers, 1998) Those recommendations state that the research and practice of complex systems' assessment should not be oversimplified and should have interdisciplinary character by assessing the same SDIs from multiple perspectives.

CHALLENGES; A PARADIGM SHIFT?

The emerging SDI concept as complex – because multi-faceted, evolving, and socio-technical - actor networks, brings paradoxes and dilemmas for research and will challenge existing theories and assumptions (see also Argyris et al. 1974: 30-34, 99-120). It goes beyond the scope of the paper to go in any detail and therefore an indicative list may suffice (for a more detailed elaboration see e.g. De Man 2008b: 37-42).

- *Breadth versus depth in assessment of SDIs.* An initial dilemma that faces research of SDI regards the breadth and depth of the inquiry. Comparative studies of SDI initiatives require conceptual consistency and stability, often resulting in a standardized framework of (key) indicators. In-depth case-studies, on the other hand, may help in the understanding of concrete SDI initiatives within their specific context.
- *Generalization versus particularization.* Assessment of SDI inevitably will face the question whether the inquiry is about generalizations on the basis of the individual SDI cases or about their particularities. In other words, the question whether the inquiry is about the SDI *concept* or about the individual SDI *initiatives*; about commonalities or about fringes and nuances – uniqueness.
- *A single, dominant view versus multiple realities.* A positivist research paradigm will operate on a limited number of theory-based perspectives. Heterogeneity – a central tenet of actor-network theory – acknowledges that the various actors may have different world views and different perceptions of reality. Moreover, a viable SDI is relevant both to the proponents of an SDI initiative and to other societal actors with otherwise diverse and often conflicting interests and values. A viable SDI, therefore, needs to balance a needed diversity in its contents and functioning on the one hand, with an equally needed standardization for technical, organizational and efficiency reasons on the other.
- *The fallacy that “more information is better”.* The many possible data sources also bring the need to choose which data will be adopted and utilized. The initial scarcity of available data is traded for the scarcity in the ability to select. This is akin to Simon’s assertion that in a information-rich environment the processing capacity to attend to information is the scarce resource (Simon 1976: 294-296). This also points to the danger of information-overload.
- *Diffusion of SDI versus ‘translation’ and negotiation.* Two alternative interpretations of the diffusion of SDI technology are possible. First, it can be viewed as the rate of adoption of an innovation through a social system and would depend on the characteristics of the innovation itself and on the differentiated innovativeness and the communication channels within the social system. This ‘pro innovation’ view is based on Roger’s diffusion of innovation model ([Rogers 1995](#)). An alternative view is that diffusion of SDI technology emerges out of interplay between human and non-human actors with different and generally conflicting interests. Or, in terms of the earlier mentioned actor-network theory, proliferation and adoption of SDI is ‘translated’ between these actors.

Is GIScience an asset or liability for SDI research?

These dilemmas challenge contemporary GIScience (e.g. Mark 2000: 48) where the GIS artefact is its core subject matter and its rhetoric is techno centred. This orientation is still clearly dominant in the position paper by [Craglia et al. \(2008\)](#) where the authors reviewed the developments in the field of information technology, data infrastructures, and earth observation that have taken place since Vice-President Al

Gore put forward the vision of Digital Earth, some ten years ago. While the need is acknowledged to develop multiple connected infrastructures that address the needs of different audiences, to be problem oriented and transparent on the impacts of technologies on the environment, and to engage in multi-disciplinary education and science, the suggested research measures still appear to remain quite unproblematic beyond technocracy. There is probably one (essential) exception to this, however. The position paper argues that progressing from specific, well-defined cases studies on well-defined scientific phenomena to more complex cases of socially defined and negotiated notions promises gradual, but significant progress (Craglia et al. 2008: 164). In a similar vein, Craglia expects SDI research to have a strong technical dimension but also to pay much greater attention to the relationships between technology, society, and governance given the inter-organizational, and political contexts within which SDIs are deployed and by which they are shaped. Hence, socio-technical, critical, and reflective perspectives must have a very important role to play in the development of this field complementing the traditional positivist scientific paradigm (Craglia 2006: 8). It seems therefore that GIScience could be enriched by adding at least two paradigms; thinking out of the artefact and thinking beyond design and construction respectively. These are not to be understood as mutually exclusive alternatives but rather as idealized viewpoints to be mixed when needed in understanding and developing concrete approaches and initiatives (as in Dahlbom et al. 1993: 71). Moreover, these viewpoints add to the conventional ones and do not necessarily replace them.

Praxis beyond the artefact

The SDI discourse whether its field is predominantly technical or not can benefit from recurrent and similar debates within the adjacent fields of public administration and information systems. These fields represent as it were the use and technology domains of SDI respectively (De Man 2008a). These debates emphasize the role of praxis. Public administration cannot be centred around a unified body of theory because of its multi- and interdisciplinary nature and the continuous changing nature of government and government-society relations (Raadschelders 1999: 281, 298). Moreover, public management must comply with different rationalities simultaneously and conciliation of them can only be achieved in case specific compromises (Snellen 2002: 323-327, 334-345). The debate in the field of information systems revolves around the question whether the artefact should be its core subject matter (e.g. Orlikowski et al. 2001: 121, who understand artefacts as those bundles of material and cultural properties packaged in some socially recognizable form). Others argue that science revolves around important questions, not around the domain per se (DeSanctis 2003: 368). Therefore, the field faces the dilemma of being able to adapt to the shifting salience of these questions and concerns and at the same time maintain a minimum identity (Lyytinen et al. 2004: 232). These debates emphasize the role of praxis. But there is another reason why the discourses in the fields of public administration and information systems are relevant for the SDI field. New vocabularies in both public administration and information systems fields are converging. For example, Hajer and Wagenaar (2003: 1-30) refer to governance, institutional capacity, networks, complexity, trust, deliberation, and interdependence as a new vocabulary for describing developments in governing the public domain. Likewise, Ciborra (1998: 12-15) speaks of care, hospitality, and cultivation in describing developments in information systems thinking. This convergence in vocabularies suggests the direction for the SDI field to develop into; networking and cultivation of socio-technical infrastructure.

Muddling through beyond construction

The SDI concept develops through various stages of maturity. Kok and Van Loenen adopt an organizational perspective and distinguish four stages of SDI development: stand alone, exchange, intermediary, and the network stage. Here, it will be insightful to draw upon the distinction Dahlbom and Mathiassen make between 'construction' and 'cultivation' in computer system development (1993: 71, 72, 128, 129). The construction approach views system development as a solution to a given data processing problem whereas in cultivation the problem is no longer given and system development is embedded in the life of the host organization. Systems developers become cultivators of organizations. Or, as Dahlbom and Janlert (1996) put it, cultivation is a conservative belief in the power of natural systems to withstand our efforts at design. This also implies that SDI – or any infrastructure for that matter – is unique and 'having a life of its own' as a network of humans and non-humans (Ciborra et al. 1998: 307, 310). The notion of cultivation also refers to risk management. (For that is what farming is all about.) The ever-continuing development process itself has to be a form of risk management if the initiative is to produce a viable SDI that is flexible enough to adapt to changing and evolving circumstances though robust enough not to break down (De Man 2008b: 34-37).

In some respect, the distinction between construction and cultivation resembles the ones made by Simon (1976) as the difference between optimizing and satisficing, or between rationality and bounded-rationality and the difference between top-down rational-comprehensive and bottom-up 'successive limited comparisons' by Lindblom (1959) in administrative decision-making. Though Etzioni (1967) suggests 'mixed-scanning' as reconciliation between these rationalistic and incrementalist approaches, Lindblom's notion of 'muddling through' where "the selection of value goals and empirical analysis of the needed action are not distinct from one another but are closely intertwined" (1959: 81) indeed seems appropriate to describe the unruly development stage(s) beyond the initial construction of SDI.

TRANSDISCIPLINARY RESEARCH IN SDI DEVELOPMENT

We now turn to the question of what approach SDI research should take in order to effectively contribute to praxis-focused knowledge in this evolving field. It is clear that the SDI field is within the realm of both technical and social sciences. This leads to the issue of disciplinary framing of SDI research. This section argues that transdisciplinarity seems to be a promising approach in this respect in that it may reconcile value conflicts between different disciplines. Actor-network theory may well be a useful operational vehicle to this end. Finally, the section sketches the contours of the required research style.

Transdisciplinary framing of SDI research

The word science is derived from the Latin word *scire*, 'to know'. Conventionally, three modes to acquire knowledge are distinguished: authoritarian, mystical, and rationalistic (Frankfort-Nachmias et al. 1996: 2-5). This distinction is somewhat similar to Weber's ideal types of legitimate authority based on charismatic, traditional, and rational grounds, respectively (1947, 1922: 328). Modern science was founded on the idea of a total separation between the knowing subject and reality, and three fundamental axioms formulated by Galileo Galilei (1602, 1632: 6): reality is subject to laws of a mathematical and universal character, these can be discovered by scientific experiment, and such experiments can be perfectly replicated. Although only classical physics has entirely and integrally satisfied these three methodological postulates, the implied paradigm of simplicity remains appealing to other scientific disciplines as well (see also Nicolescu 2002: 9-14); even to some of the social sciences. But the question is legitimate whether human social life can really be

studied in this scientific way (Giddens 2006: 77) and whether theory in the social sciences is possible similarly as in natural sciences (Flyvbjerg 2001: 25-27). Though human behaviour and thus social life is subject to norms, culture and institutions, these are incomparable with the deterministic laws in the natural sciences. Moreover, in social sciences objects are subjects (Flyvbjerg 2001: 32). The distinction between natural (or technical) sciences and social sciences is particularly relevant for SDI research because it clearly points at the complexities that are implicated. For example, the research project SPATIALIST (Spatial Data Infrastructure and Public Sector Innovation) in Flanders (Belgium) is carried out in a disciplinary combination of public administration, sociology, law, and economics within the social sciences, and geomatics within the technical sciences to guarantee a comprehensive view of the development of an SDI (Crompvoets et al. 2008a).

With the passing of time, scientific knowledge became more and more specialized and is build and maintained within an ever-growing number of different disciplines. In this paper we use the term 'discipline' as a set of coherent intellectual constraints – focus of study, rhetoric, paradigms, rationalities, and methods – embraced by the members of a scientific community. Conversely, the members of that community share those values (e.g. Kuhn 1970: 176; Lyytinen et al. 2004: 226; Max-Neef 2005: 6; Pinch 1990; Winder 2003: 75). The relation between intellectual values and membership of a distinct community may easily lead to what could be called a 'political economy of disciplinarity'; who benefits and who loses. (The paper returns to this in the final section.) The question then arises whether SDI research would thrive best within a special discipline of its own or be supported by a variety of disciplines. The paradoxes and dilemmas for SDI research that were mentioned before will undoubtedly challenge the required intra-disciplinary coherence and therefore makes the former option unlikely. Consequently, as in the Flanders case, teams of researchers from different disciplines have to be formed. This, in turn, will demand coordination between the different disciplines involved. In the literature several types of doing so are found as a continuum that goes from no coordination to full coordination between the disciplines; interdisciplinarity (e.g. Max-Neef 2005; Nicolescu 2002; Tress et al. 2003). But the knowledge that is required may exceed the sum of disciplinary knowledge in a fundamental way. This is the idea of 'transdisciplinarity'. Nicolescu refers to the example of quantum physics with a different level of reality than that of classical physics and with different 'laws' and logics accordingly (2002: 15-22). Others see transdisciplinarity to indicate a kind of research that involves stakeholders who are not academics (e.g. Winder 2003: 75). This does not necessarily mean that those stakeholders are member of the research team but rather that their realities and rationalities are accounted for in the research. In researching an SDI this would mean that its "life of its own" would be taken seriously.

Theoretically, transdisciplinarity acknowledges different levels of reality. That is to say those two levels of reality are different if there is a break in the governing laws and a break in fundamental concepts such as causality, between them (Nicolescu 2007: 21). One could argue that interdisciplinarity is a form of transdisciplinarity though the latter also goes beyond the disciplinary realm. The notion of 'levels of reality' is significant for handling paradoxes and dilemmas as in SDI development. Assume that one has to choose between an option and its opposite; for example between maximum standardization and maximum flexibility in the design of an SDI. The dilemma is as we have seen that one needs both. Classical logic of Aristotelian tradition says that this is not possible (except by a compromise that would necessitate the relaxation of 'maximum' in both options). In other words, there is not a 'third' that assumes the validity of something and its opposite at the same time (the 'axiom of the excluded middle'; Nicolescu 2002: 26). Transdisciplinarity assumes that

mutually excluding opposites can be reconciled from a different level of reality (the axiom of the 'included middle'; 2002: 28, 29). Intuitively, transdisciplinarity is 'thinking out of the box' – specifically, out of the disciplinary box. For SDI development, the reality of the "SDI-life of its own" beyond the disciplinary reality may provide for such 'included middle'.

Finally, both inter- and transdisciplinarity are praxis-focused. They only exist within the context of actually doing research. To again paraphrase Latour, inter- and transdisciplinary actors have to do something, not to be placeholders. This is not necessarily the case for disciplinary researchers.

Actor-network theory: assembling the SDI transdisciplinary

While the paper understands SDI as an evolving actor network where heterogeneous actors are engaged in a continuous process of negotiation, the same apparently applies to the transdisciplinary research – or interdisciplinary research for that matter – that is required for its research. This is not by coincidence and akin to Asby's 'law of requisite variety' stating that a situation can only be controlled – or studied – if the variety of the controller matches the variety of the situation to be controlled (1956: 206-213).

Actor-network theory is by its very nature not a unified body of concepts and approaches. Nevertheless some general consensus can be found in the literature. Actors – both human and non-human – have to do something and make a difference. Specifically, they make other actors also do things; for example they make them to cooperate. Not by force or causality but by 'translation' between them (Latour 2005: 107, 108, 154, 217) – a phased process whereby the identity of actors, the possibility of interaction and the margins of manoeuvre are negotiated and delimited. It is a process, never a completed accomplishment (Callon 1986: 196, 203; see also Woolgar 1991). In other word, translation is ongoing negotiated alignment of actors into specific roles and the associated actions. Actor networks are assembled in these processes of interacting actors ([Callon 1985: 24, 28, 33; Latour 2005: 169, 179](#)). Translation signifies two things. First, actors have their own interests, beliefs and other values. Second, value conflicts are negotiated by translation and within the reality of the emerging actor network.

Multidisciplinary teams in SDI research will be frequently confronted with paradoxes and dilemmas; specifically those within the multidisciplinary team. Interdisciplinary paradoxes and dilemmas may be reconciled by an 'included middle' from within the reality of the SDI under investigation. In other words, transdisciplinary SDI research is to acknowledge this reality by involving its actors and stakeholders. This does not deny of course the specific role researcher have to play. And, rather than embracing too quickly preconceived, theoretical and conceptual perspectives, Latour advises the researcher just to follow the trails of these actors myopically like ants (2005: 165-172, 176).

Towards socio-technical SDI research

Social sciences offer a set of methods that are promising for transdisciplinary SDI research as, for example, ethnography, surveys, experiments, life histories, comparative research, historical analysis (e.g. Giddens 2006: 85-92). Flyvbjerg (2001: 56, 57, 60-62) argues that a "social science that matters" must deliberate about values with reference to praxis and hence be pragmatic, variable, context-dependent, and oriented toward action (which he refers to as "phronetic social science" – prudent and practical common sense). He offers some guidelines for such

social science: focussing on values, placing power at the core of the analysis, getting close to reality, emphasizing little things, looking at practice before discourse, studying cases and contexts, asking “how?” and doing narratives, joining agency and structure, and dialoguing with a polyphony of voices ([Flyvbjerg 2001: 129-140](#)).

The fields of information systems and infrastructure show an increasing interest in interpretive studies besides conventional positivist approaches. Interpretive studies attempt to understand phenomena by accessing the meanings that participants assign to them. Generalisation from the setting is not sought; rather the intent is to understand the deeper structure of a phenomenon which it is believed can then be used to inform other settings ([Orlikowski et al. 1991](#)). [Star \(2002\)](#) argues for the relevance of ethnographic practices when studying information infrastructures. Ethnographic fieldwork focuses attention on fringes and nuances as well as the practical materialities (concreteness) of infrastructures. It helps to read the invisible layers of control and access and to understand the changes in the social ordering that result. Its strength is that it is capable of surfacing silenced voices, juggling disparate meanings and understanding the gap between words and deeds ([Star 1999](#)). [Myers \(1999\)](#) contends that ethnography often challenges what we “take for granted” and provides IS researchers with the opportunity to get close to “the action”. Regarding IT evaluation, [Hedman and Borell](#) propose the use of narratives because this can grasp the complexity of information systems better than traditional postevaluation approaches ([Hedman et al. 2005](#)). Four features characterise a text or discourse as ‘narratives’ – the sequence in time, focal actor(s), an identifiable narrative voice, that they embody a sense of what is right and wrong, appropriate or inappropriate, and so on (see also [Pentland 1999](#)). Narratives can be the stories told by actors that were, and are, involved in SDI development but [Star \(1999\)](#) understands that most information infrastructures themselves will also have an inscribed narrative. The task would then be to identify and surface the master and subsidiary narratives.

The most characteristic feature of any research process – including the social sciences – is its cyclic nature (e.g. [Frankfort-Nachmias et al. 1996: 20](#)). [De Groot \(1969: 1-18\)](#) stresses the indispensability of the empirical cycle in such phenomena as experience, goal-striving behaviour, learning, problem solving, directed and creative thinking. Indeed, this is what researchers and practitioners have in common. [Lawas \(1997\)](#), for example, shows this ‘scientific’ (learning) behaviour of the Kankanaey farmers in Benguet. Likewise, [Peters Guarín \(2008\)](#) demonstrated the collaborative learning of the researcher and local communities in Naga City regarding flood risk assessment. Though both studies were carried out by individual researchers, they clearly show transdisciplinarity of their research.

Finally, what are the SDI research questions that might be tackled by a transdisciplinary research approach? Probably the most challenging question for a transdisciplinary research is the interaction of the SDI components. It is now commonly accepted that SDIs consists of five components technology, spatial data, standards, policy and people. It is our hypothesis that a sustainable SDI can only evolve when balanced attention is given to development of all individual components and their mutual interactions. The scientific disciplines supporting the various components are quite different. For instance, technology is a engineering and computer science disciplinary field, spatial data is the domain of geographical information science, people and policy are clearly social science areas. For research on SDI a combination of research approaches from the different disciplines or maybe even an derived research approach is needed. Transdisciplinarity might be the right paradigm to innovate our SDI research.

SO WHAT?

The transdisciplinarity that is proposed for SDI research will undoubtedly challenge contemporary GIScience with its predominantly techno centred orientation and positivist paradigm. In this final section we briefly explore and anticipate its possible consequences for the research community; specifically for its academic organization and individual members. As it was mentioned before, scientific fields (notably disciplines) comprise a contentious relationship between a coherent set of intellectual values and a community that embraces these values. Science is a community-based activity with tight control of rewards, recognition, and sanctions by such means as peer review for grants and publications (Pinch 1990: 297). In other words, science is a social process where elements as interests, rhetoric, 'closure mechanisms', are important in striving for control and thus in social ordering. Traditionally, science has been the domain of faculties, schools, and other academic institutions. Legitimacy of these communities is important for the same reasons: rewards, recognition, and sanctions; but now between these institutions. Hence, social ordering is both within and between scientific communities. The current publication culture favours increasingly narrowly focused and highly specialized papers. Attempts to synthesize and pull together these special research results into broader analysis are minimal at best (e.g. Hirschheim et al. 2003: 277). This condition effectively contributes to developing an inward-looking and defensive disciplinary culture. Against this background, transdisciplinarity challenges the academic 'enterprise' in two directions. First, it threatens the existing social order of disciplinary scientific communities. Second, though related, transdisciplinarity threatens the values (intellectual constraints) that define the established scientific communities. Conversely, of course, established academic institutions may attempt to change these challenges into barriers for transdisciplinarity to enter the academic scene. The need to remove these barriers is becoming more widely recognized. For example, the NSF Workshop on Social Organization of Science and Science Policy, held in 2006, observed that

"NSF funding initiatives can play a powerful role in creating funding incentives for truly interdisciplinary and transdisciplinary research. Transdisciplinary science faces considerable cultural, structural and organizational barriers. By creating such research opportunities and revamping the evaluation of these efforts, NSF sends a strong legitimating signal to relevant policy makers, research organizations and administrators and may topple some of these barriers" (Cozzens et al. 2008: 20).

Because there is not much evidence that mainstream GIScience is more inclusive toward transdisciplinarity than other (established) scientific fields are presently, this leads to the question of how individual transdisciplinary SDI researchers relate to contemporary GIScience. Each SDI academic must find a reasonable place to stand while being engaged in this social process. A two dimensional frame may clarify the available options she or he has (Lyytinen et al. 2004: 237-241). The first dimension is about how one sees the academic community: primarily as a vehicle for one's career advancement or as an incidental aggregate of people with shared interests. The second dimension involves the choice of whether or not to conform to established theoretical constructs and modes of inquiry in the academic field. These two dimensions constitute a two-by-two matrix. The two 'poles' of the main diagonal respectively represent established and continuously emergent academic fields – "the dynamic of the provisional" (Schütz 1965). It can be argued that those who are relatively peripheral to contemporary GIScience – or any of the related disciplines – fit well in transdisciplinary research activities. [This would be akin to Granovetter's 'strength of weak ties' (1973).] These 'peripheral' academic actors from different

academic fields may develop into 'communities of practice' when sharing the praxis of transdisciplinarity (e.g. DeSanctis 2003).

Finally, what will happen if transdisciplinarity is not a "flash in the pan but here for the long shot"? Then the question seems to be legitimate whether transdisciplinary SDI research or contemporary GIScience will be peripheral in future.

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