

IS SUSTAINABILITY RESEARCH: A TRANS-DISCIPLINARY FRAMEWORK FOR A ‘GRAND CHALLENGE’

Completed Research Paper

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Abstract

To address the “grand challenge” of biosphere sustainability, it is imperative that we examine the assumptions and philosophies underlying Information Systems sustainability research and expand research approaches. Despite calls for trans-disciplinary research and recognition that addressing sustainability will require multiple perspectives, a review of the IS sustainability literature finds that few publications incorporate knowledge or methods from outside traditional business-centric boundaries. Drawing on a diverse range of IS and sustainability literature, we develop a trans-disciplinary framework for IS Sustainability Research (ISSR) based on a view of sustainability that recognizes the environment as a critical stakeholder rather than a collection of resources to be managed and exploited. We identify three broad areas of inquiry and representative research questions which address the connections between human activity, the natural capital of the biosphere, and the societal goals of human-environment interactions through which ISSR can contribute to the grand challenge of biosphere sustainability.

Keywords: Environmental sustainability, Framework, Trans-disciplinary, Green IS and Sustainability, System dynamics

Introduction

The Information Systems (IS) community is increasingly interested in elevating the role of socio-technical systems in reversing the current trajectory of environmental degradation (Melville 2010; Watson et al. 2010). Serious threats to humans, other species, and the biosphere at large are the results of unsustainable practices of consumption and waste production. Changes in behaviors and attitudes at all levels - individual, community, and organizational - will be required to create circumstances in which the overall biosphere and human culture can flourish synergistically. IS research has touched on a variety of pertinent domains including Green IT, Green IS, sustainable development, and industrial ecology. This research has focused on specific aspects of sustainability, such as energy informatics, environmentally friendly computing infrastructure, or sustainable business practices, while taking a highly business-centric perspective.

Previous authors have suggested that IS research is undervalued because the community does not engage the 'grand challenges' and compelling problems in which IS knowledge is relevant (Winter and Butler 2011). By definition, grand challenges demand trans-disciplinarity, development of new research and organizing capabilities, and sustained effort over decades. Sustainability, at the level of the entire biosphere is an example of such a grand challenge as it requires trans-disciplinary knowledge creation, new research and practice methods, extensive integration of information and supporting technical systems, and a long-term research program.

IS is uniquely situated to transcend disciplinary boundaries and rich research questions lie in the gaps between the traditional boundaries separating the business, humanities, and scientific disciplines (Galliers 2003). For IS to contribute to the grand challenge of achieving biosphere sustainability, the need for trans-disciplinary efforts is compounded by the complexities inherent in sustainability. Sustainability is a characteristic of a 'system', which is itself comprised of interacting subsystems including individual and collective behaviors and values, supply and demand relationships, technology, geophysical and biological systems, and resource utilization rates and replenishment constraints. Thus, the shift to sustainable practices is not a problem which can be solved by a single discipline. In order to facilitate substantive research and action with respect to sustainability, it is critical for the IS community to identify the terms and assumptions of research, the trans-disciplinary components of such research, and an expansive set of problems that should be addressed. In this paper, we propose a trans-disciplinary IS Sustainability Research (ISSR) framework to guide IS research across the broad spectrum of sustainability issues. This framework highlights the potential deployment of information systems across multiple research domains, which must be integrated to understand the challenges and opportunities for biosphere sustainability.

As both IS and sustainability research are enhanced by trans-disciplinary perspectives, this paper draws on the literatures in IS, ecology, environmental management, and the natural sciences to formulate a framework to motivate and guide IS-originated, trans-disciplinary sustainability research. We note that the use of the term "trans-disciplinary" is relatively new in the IS literature, with the first reference being found in Galliers (2003). This discussion of a trans-disciplinary approach within IS arose in reaction to the vigorous debate at the time regarding the essence of the IS discipline (Benbasat and Zmud 2003). The article differentiates multi-disciplinary and trans-disciplinary perspectives, defining trans-disciplinary research as "investigating the spaces between traditional disciplines" (Galliers 2003, p. 345). Six dimensions on which IS-disciplinary and trans-disciplinary perspectives vary are described: the boundary, central artifact, focus, scope, reference disciplines and properties, and the author argues strongly in favor of trans-disciplinary approaches within IS. Cronin (2008) identifies four core characteristics of trans-disciplinary research: focus on lifeworld problems; transcending disciplinary paradigms; participatory research, and a search for transformational knowledge. Using these attributes of trans-disciplinary research, we first examine the occurrence of trans-disciplinary research in IS and find that, despite numerous opinions and calls for work of this nature, self-identified trans-disciplinary research remains rare in mainstream IS journals. Additionally, we find that sustainability research in the major IS journals has remained predominantly situated within the organizational context (Jenkin et al. 2011) and is underpinned by an unacknowledged theoretical basis that is well articulated in Ecological Modernization Theory (EMT) (Mol and Janicke 2009). As its basic premise, EMT assumes that environmental sustainability is a managerial or technologically determinant problem, thus focusing the contributions of IS on traditional business domains. A trans-disciplinary approach would expand the

domain of research questions for IS researchers by transcending the disciplinary boundaries of current research.

Although existing sustainability research in IS serves to elevate the importance of environmental issues, it also raises concerns regarding the future of IS sustainability research scholarship. First, the dominant perspective views nature as an object, something which can be controlled by human systems. Secondly, the belief that environmental problems can be solved with technology using traditional management approaches has led IS researchers to look within, rather than outside, the field to try to ‘solve’ the environmental problem. However, deep understanding of the dimensions and complexities associated with biosphere sustainability requires the recognition that sustainable maintenance of human systems (economic, cultural, physical) must occur *within* the overall biosphere system.

In response to these concerns, we refer to two observations to inform our approach. First is the recognition of the beginning of the Anthropocene, an epoch where human activity is a force of nature shaping the environment and the biosphere (Steffan et al. 2011). Second is the deployment of information systems across academic disciplines, business contexts, and most areas of human activity. IS is uniquely positioned at the intersection of knowledge creation and dissemination in multiple disciplines and can serve to integrate the status and trends in the biosphere, the impacts of human activities on the biosphere, the formation of attitudes and behaviors of organizations and people in relation to the biosphere, and long-term system effects with the biosphere. The strong coupling between economic, socio-political, biological, geophysical, and atmospheric systems increases the need for trans-disciplinary knowledge management, information access and distribution, and decision support. These needs can be addressed by well-founded IS sustainability research.

In this paper, we argue that trans-disciplinary research transcending the boundaries of the traditional IS discipline *and* the traditional business domains will provide critical knowledge of human-biosphere interactions at multiple levels, thus addressing questions salient to the ‘grand challenge’ of sustainability. Fruitful IS research lies in a multitude of domains which bridge business, organizations, science, and humanities including but not limited to, support for citizen science initiatives, the influence of social networks and media, social impact analysis, environmental visualization, geospatial group decision making, and sensor networks for reclamation and rehabilitation efforts. Thus, the goals of this paper are threefold:

1. to review trans-disciplinary efforts in IS research;
2. to identify and question the epistemological assumptions which underlie current sustainability research in IS; and
3. to present a framework and exemplar research questions for ISSR that reflect trans-disciplinarity.

The paper is organized as follows. First, the results of a literature review examining trans-disciplinary research in IS are presented. This is followed by a discussion of sustainability research in the major IS journals, with the goal of highlighting the key epistemological and theoretical underpinnings of IS sustainability research. Then, drawing on a broader selection of sustainability literature, the paper proposes an alternative perspective on sustainability and develops a framework for trans-disciplinary IS Sustainability Research (ISSR). The applicability of the ISSR framework is demonstrated by outlining three broad research domains and attendant research questions for future IS research. Finally, the paper concludes by summarizing the contributions and limits of this research.

Literature Review: Trans-disciplinary Research in IS

To set a baseline for trans-disciplinary sustainability research in IS, our first step was to understand how the term “trans-disciplinary” is used in the IS literature. Recognizing that different concepts, such as multi-disciplinary, cross-disciplinary, inter-disciplinary, and trans-disciplinary, have been used to refer to various forms of boundary spanning research, we choose the specific term ‘trans-disciplinary’ to reflect a paradigm shifting approach to research. Trans-disciplinary research goes a step further than inter-disciplinary research and ‘redraws the map’, resulting in the evolution of disciplines, and developing approaches that generate over-arching and comprehensive knowledge synthesis (Cronin 2008). This search addresses the first goal of our study, which is to examine how trans-disciplinarity is viewed within the IS literature.

Methods

The literature review was conducted in April 2012 via the ABI Inform Global and Web of Science databases, using the key words “information systems” in combination with “trans-disciplinary” or “transdisciplinary”. No limits on publication date were applied. In Web of Science, the keywords were specified as appearing in the topic, while for ABI Inform, the keywords could appear anywhere in the text. Articles published in the AIS Senior Scholars’ basket of eight journals (European Journal of Information Systems, Information Systems Journal, Information Systems Research, Journal of the AIS, Journal of Management Information Systems, MIS Quarterly, Journal of Strategic Information Systems and Journal of Information Technology) were chosen for a focused search as these journals represent the main stream publication outlets for scholars within the IS field. Following the identification of an article, the full text was read to determine how the concept of trans-disciplinary research was reflected. Those articles that referred to “trans-disciplinary” only in terms of author interests or in the list of references were removed from the sample, resulting in a total of 17 articles.

Results

We list the content and type of IS papers that refer to trans-disciplinary approaches (Table 1). Ten of the papers are editorials, commentaries, opinions, or introductions to special issues. The remaining seven are research articles on a range of IS topics including open source (von Krogh and Spaeth 2007), virtual teams (Raghuram et al. 2010), infrastructure studies (Edwards et al. 2009), technology-mediated learning (Gupta and Bostrom 2009) and business transformation (Elliot 2011). With an average of 1.7 articles per year, trans-disciplinary research occupies a small space in the mainstream IS literature. The results also suggest that receptivity to publishing trans-disciplinary work is mixed, with three journals (EJIS, JAIS and JIT) accounting for 82.3% (14 of the 17) articles published. There is also a strong concentration of trans-disciplinary articles among authors, with six of the 17 articles being authored or co-authored by Galliers (see Table 1).

Table 1. Trans-disciplinary articles by type				
	Commentary, Editorial, Opinion or Introduction to Special Issue		Research Paper	
IS Discipline and research methods and theory	(Galliers 2003)	JAIS	(Merali 2006)	EJIS
	(Bhattacharjee 2004)	EJIS	(Galliers and Huang 2012)	EJIS
	(Merali and McKelvey 2006)	EJIS	(Winter and Butler 2011)	JIT
	(Galliers 2008)	EJIS		
	(Wastell and McMaster 2008)	JIT		
	(Hassan 2011)	EJIS		
	(Galliers 2011)	JIT		
Knowledge and learning	(Galliers 2006)	EJIS	(Gupta and Bostrom 2009)	JAIS
	(Newell and Galliers 2006)	EJIS		
Open source			(von Krogh and Spaeth 2007)	JSIS
Infrastructure studies	(Edwards et al. 2009)	JAIS		
Virtual work			(Raghuram et al. 2010)	ISR
Sustainability			(Elliot 2011)	MISQ

Implications

The results of this study provide an interesting view of trans-disciplinary research in IS. There appears to be some recognition that trans-disciplinary approaches can be very helpful to advancing IS scholarship (Galliers 2003) and that the IS discipline is well-positioned to contribute to trans-disciplinary problems

and phenomena (Merali and McKelvey 2006). Further, as Elliot (2011, p. 231) comments: “the different perspectives are seen to be complementary, not competing. Independent studies within each discipline may be of some academic interest but a trans-disciplinary study on a high visibility issue like changed behavior to improve the environment has relevance for all stakeholders with immediate and substantial impact”.

Despite the recognition of the value to be derived from trans-disciplinary research (Galliers 2003), few empirical trans-disciplinary research papers have been published in these eight journals. In 2006, the European Journal of Information Systems published essays and commentaries from different disciplinary perspectives to provide a “first step toward the rather more difficult task of developing a truly trans-disciplinary perspective” (Newell and Galliers 2006, p. 442). The use of complexity science concepts were proposed to support trans-disciplinary research by not only spanning the discourse across the “management field, but also across the natural and human sciences” (Merali 2006, p.226). Authors von Krogh and Spaeth (2007) reviewed the open source literature across different disciplines and found that open source provides a prime opportunity for trans-disciplinary dialogue. Encouraging other researchers to adopt a trans-disciplinary perspective, they identify five questions for IS research to consider (Table 2).

Table 2: Questions to guide IS trans-disciplinary research (von Krogh and Spaeth 2007, p.250)
<ol style="list-style-type: none"> 1. What is the relationship between social values and information systems in society? 2. What are the current and emerging social and economic phenomena that deviate from existing and accepted theory and assumptions in information systems research? 3. What characterizes the quality of data in information systems research that explores a new phenomenon? 4. How can information systems research strengthen its interaction with a broad set of phenomena? 5. In which areas of inquiry is proximity between science and the phenomenon instrumental in enabling information systems researchers to pose interesting and relevant research questions?

But knowing *how* to do trans-disciplinary research is much more difficult than merely stating that we should (Lawhon et al. 2010). As an initial step we use these questions in the development of a conceptual, trans-disciplinary framework for ISSR. First, we briefly review the existing IS sustainability literature, to identify the underlying perspectives and assumptions.

Sustainability Research in IS: Existing Approaches

Multiple research agendas have been proposed with respect to IS and environmental sustainability and we are guided by relevant elements of the existing frameworks. The most prevalent approach is one grounded in corporate influence. Sustainability research in IS has been defined as an investigation into “IS-enabled organizational practices and processes that improve environmental and economic performance” (Melville 2010 p. 2) and has been envisioned as an opportunity for IS “to tackle sustainable development while improving productivity, reducing costs, and enhancing profitability” (Watson et al. 2010 p. 24). Other research draws on the management, environmental psychology, and social marketing domains and strives to “place Green IT/S into the broader context of corporate environmental sustainability” (Jenkin et al. 2011, p. 18). Although incorporating “environmental impacts” as part of the model, the paper brushes over this concept at a very high level and acknowledges the research to date is largely conceptual and that there is a gap related to understanding the measurement of environmental impacts.

Melville (2010, p. 3), proposes a “conceptual framework for framing research issues at the intersection of information systems, organizations, and environmental sustainability”. As such, the proposed framework privileges organizations and remains fundamentally situated within a techno-managerial context in which environmental sustainability is a managed outcome. Dedrick (2010) approaches the question of IS and environmental sustainability from a traditional input-process-output perspective. Concerned with the relationship of IT and carbon productivity, he suggests four topical areas for future research which place the production process above both IS and environmental sustainability.

A new sub-discipline of energy informatics proposes to break “away from the dominant social sciences paradigm to embrace a solution sciences approach, which incorporates fields such as management science, design science, and policy formation” (Watson et al. 2010, p.3). At the heart of the model, information systems provide the integration between energy demand and suppliers, across four main components of the energy management system. This research model is IS-centric and limits sustainability to a focus on energy efficiency. While it is true that the generation and consumption of energy plays a key part in climate change, it presents a highly simplified view of the complexity of sustainability and focuses on organizational goals.

At the individual level, a thematic survey of the role of HCI for sustainable development (DiSalvo et al. 2010) reveals a focus on IS as a persuasive technology which can alter individual action, rather than as a means to coordinate collective, political or regulatory activities. At the organizational level, recent IS literature has expanded the research domain to encompass organizational strategies focused on the Triple Bottom Line (TBL) framework (Elkington 1997), eco-strategies such as eco-efficiency, eco-equity and eco-effectiveness (Jenkin et al. 2011), and IT-enabled business transformation (Elliot 2011). In decision support systems research, a common theme is the development of multi-criteria decision-making techniques applied to a wide variety of environmental problems (Pohekar and Ramachandran 2004).

By reviewing the extant literature related to IS and sustainability we see that the current frameworks and exemplar problems are largely focused on organizational concerns including energy consumption, resource and material usage, level of emissions, and waste management (Melville 2010; Watson et al. 2010). These factors privilege organizational productivity, costs, and profitability rather than addressing fundamental values and scientific issues of environmental sustainability. Each organization is treated as an isolate with the view that if one, or one hundred companies, reduce the rate at which their energy/material consumption increases, environmental sustainability can be achieved. But simple reductions in the rate at which consumption of non-renewable resources are increasing will only extend the lifespans of the resources, not alter their ultimate exhaustion (Bartlett 1994). This perspective ignores the dynamic nature of the natural world, the evolution of ecosystems and environments, and the effects of increasing consumptive demands from a burgeoning population. Researchers must be careful to identify *ceterus parabus* assumptions and recognize that practices which may be sustainable for a global population of 7 billion people are unlikely to be sustainable for a mid-range prediction of 10.1 billion people by 2100 (United Nations 2011b).

Challenging Underlying Assumptions

In addition to having an organization-centric perspective, IS sustainability research frameworks are constrained by underlying theories and models and thus warrant exposition and closer examination. Due to the complexity of environmental concerns, it is essential that we critically assess the theoretical foundations on which our research and human systems are based (Dourish 2010). To accept these models without scrutiny is inherently self-limiting and restricts our ability to develop a richer comprehension of the phenomenon under investigation. Just as Watson et al. (2010, p. 24) argued that a focus on Green IT “is too narrow and should be extended to information systems, which we define as an integrated and cooperating set of people, processes, software, and information technologies to support individual, organizational, or societal goals”, we argue that the focus of IS sustainability research on business-oriented information systems is too narrow. Rather, our collective view should be expanded to envelope trans-disciplinary work which explicitly recognizes the strong coupling of the many systems which comprise the *biosphere*.

The term *sustainability* and the misnomer of *sustainable development* are claimed by many different actors who use the terms in various social, political, environmental, and developmental contexts (Norton 2005). A widely adopted definition of sustainability¹ (Brundtland 1987) implicitly assumes that natural and man-made capital are substitutable with one another and asserts that sustainability can be achieved within a growth economy while ignoring the dynamic that growth is intimately linked to environmental degradation (Pearce 1993). This definition is aligned with the precepts of Ecological Modernization Theory (EMT) (Mol and Janicke 2009). The key premise of EMT is that environmental problems at the

¹ “development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”

global scale can be solved within our existing or slightly modified social, political, and economic structures without compromising capitalistic objectives of economic growth, globalization, and wealth accumulation (York et al. 2003). Further, EMT proposes that ecological impacts decrease as industrialization increases due to ecological rationalization. The driving forces of EMT are institutional restructuring, technological innovation, market forces, new social movements and government regulation (York et al. 2003).

Although EMT is intuitively appealing, particularly for those involved with the innovation of new systems and technologies, a number of weaknesses have been identified with the theory (Fisher and Freudenburg 2001; Kondoh 2009). EMT has been criticized as being overly optimistic in regard to technological capabilities (Hannigan 1995), and empirical studies have questioned the veracity of EMT to achieve environmental goals (Kondoh 2009; York et al. 2003). Practically, the demands of the macro-economic system and reified organizational goals emphasize growth and an overall increase in resource usage, albeit more efficiently (Meadows 2008). Even with the application of state-of-the-art environmental practices and environmental management information systems, organizations are ultimately increasing their total ecological footprints when they grow to serve higher consumption demands (Gray and Milne 2002). This problem is compounded because common definitions of sustainable development rarely identify assumptions about future standards of living, population size, climatic instability, or duration. The debate regarding the economic and political feasibility and lack of postulates and evidence for EMT (Fisher and Freudenburg 2001) suggest that IS sustainability research should question these fundamental assumptions as part of the research process.

A contrasting conceptualization views sustainability as a concept that entails a comfortable standard of living for the world's population *within the capacity of nature* (Jackson 2009), consuming earth's resources no faster than they can be naturally replenished. This perspective emphasizes the maintenance of natural capital and recognizes that ecosystem services, such as clean water supplies, CO₂ sequestration by vegetation and oceans, and agriculturally productive soils, are non-substitutable and essential for the welfare of human beings (Pearce 1993). The statement that "the term sustainable growth should be rejected as a bad oxymoron" (Daly and Townsend 1993 p. 6) acknowledges that increasing resource consumption through usage of more land, more water, more food stocks, and the production of more 'things' for more people is not sustainable.

We posit that biosphere sustainability means ensuring that natural ecosystems, species distribution and diversity, and climatic conditions remain intact and viable concomitant with the fulfillment of human well-being. This perspective does not privilege the value of human activities over the environment, nor assume dominance over the earth by humans. Further it acknowledges that artificially created "ecosystems" (e.g., tree farms, managed parklands, reclaimed mine scars) have diminished value compared to relatively intact natural systems and that human well-being needs to be redefined in terms other than material wealth accumulation.

Another of the assumptions in much of the IS sustainability research is the analytic separation of the *natural* environment from the social components (e.g. consumers, corporations, government, economy); the natural environment is seen as being external to the organizational system. Research has tended to restrict the role of information systems to managing the inputs from, and the outputs to, the environment. This view artificially bounds the scope of IS research to managerial functions and obscures the need for trans-disciplinary research. It also views the biosphere as a resource to be managed and consumed rather than positioning the natural environment as an essential stakeholder (Driscoll and Starik 2004) and actor in the achievement of sustainability.

An alternative assumption is to recognise that sustainability is a normative ethical concept not an analytic one. To change trajectories to sustain the biosphere system requires choices that are societal, not technical or scientific (Spangenberg 2005). The dynamic characteristic of the interrelated systems which constitute the biosphere requires knowledge of both the constituent parts and their interactions, and consideration of the values reflected in human choices which impact the entire system. What is neglected in the dominant IS view is that there are definitive limits on the global ecosystem and that exceeding natural limits has serious consequences for biosphere sustainability. A trans-disciplinary perspective acknowledges that there are continuous and complex interdependencies between human activities and the environment (Woodgate and Redclift 1998). Organizations transform the environment to fulfill human needs such as living space, raw materials, and the disposal of human waste. But simultaneously, the

natural environment constrains the activities of organizations and the opportunities of future actors because there are fixed limitations to the availability of natural resources and ecosystem services. The goal of a sustainable biosphere, not merely sustainable business, requires a different mind-set than is currently reflected in designing information systems to manage specific input-output processes. It is a mindset that requires a systems approach (Meadows 1998; Winter and Butler 2011) which recognizes dynamic and non-linear system behaviors and necessitates looking beyond traditional IS boundaries to inform research in a broader trans-disciplinary approach. We note there has been little direction to date on what this means for IS sustainability research.

Defining Trans-disciplinary Research for IS

As discussed, the underlying assumptions in the extant sustainability research in IS promote a narrow disciplinary focus, and do not encourage the exploration of new phenomena or deviation from managerial theorizing. It has been suggested that the multi-disciplinary nature of sustainability research may in part explain why IS lags behind other fields in addressing questions of sustainability (El-Gayar and Fritz 2006). Also, as the review of IS trans-disciplinary research implies, publication of trans-disciplinary work in IS may also provide a practical barrier for IS scholars. Unquestionably, undertaking trans-disciplinary research is challenging given the absence of a clear definition for trans-disciplinary research within the field of IS. The most explicit definition to be proposed thus far is that trans-disciplinary research investigates “the spaces between traditional disciplines” (Galliers 2003, p. 345). Although this description helps to differentiate disciplinary from trans-disciplinary work, it provides little concrete direction for IS scholars.

In contrast, outside of IS, there is a rich literature on trans-disciplinary research. Trans-disciplinary research is viewed as a specific form of inter-disciplinary work that, in addition to recognizing the importance of different scientific fields, emphasizes the need for cooperation and communication across various parts of society to address complex challenges (Tappeiner et al. 2007). Trans-disciplinary research has been described as a “process where the team jointly defines research questions and develops research designs that integrate theoretical knowledge and practical problem solving” (Espinoza-Tenorio et al. 2010, p. 746). Trans-disciplinary research also requires spanning of institutional boundaries, integrating empirical, pragmatic, normative and values knowledge (Max-Neef, 2004) and transcending the boundaries between research and action (Farley et al. 2010). In sum, trans-disciplinary research involves more than looking at phenomena from multiple disciplinary perspectives, it requires self-reflection and testing of underlying and implicit assumptions, and synthesis of ideas across multiple different perspectives (Lawhon et al. 2010).

These perspectives from outside of IS can be useful for helping to define trans-disciplinary research within the context of IS. To this end, we initially build upon Galliers’s (2003) work to refine the foundational issues of trans-disciplinary ISSR (Table 3).

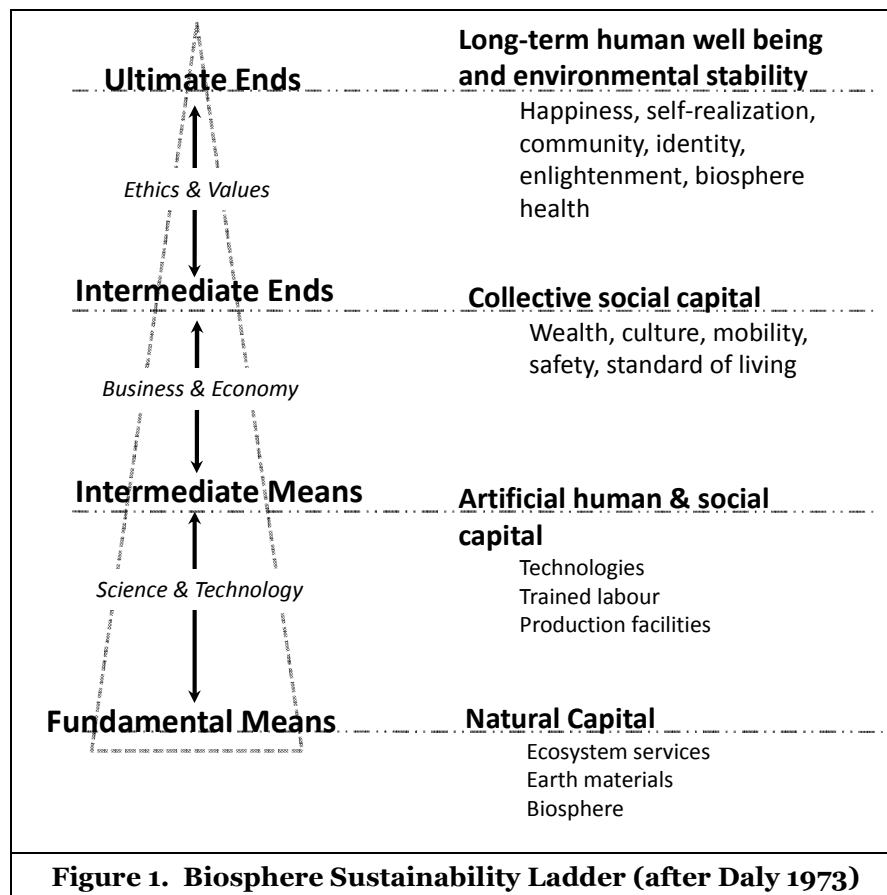
Table 3: Foundational issues of trans-disciplinary ISSR*			
	Disciplinary	Trans-disciplinary	Sustainability-focused trans-disciplinary
Boundary	Organization	Society	Biosphere
Scope	Narrow	Broad	Holistic
Focus	Inward	Outward	Integration of system knowledge
Central artifact	IT	People/information	Natural, human and social capital
Reference disciplines	OB, Computer Science, etc.	IS	IS, sustainability, ecology, environmental management, social psychology
Trans-disciplinarity	A threat	An opportunity	A necessity
*adapted from (Galliers 2003)			

Attendance to these core characteristics will enable researchers to better communicate the research questions, goals and outcomes of research. First, the boundaries of such research are extended beyond human constructions or organizations and societies to consider the full biospheric system. The scope of such research is holistic with a focus on the integration of systems knowledge in totality. The discipline-centric inward or outward focuses become irrelevant as the goal is to understand the interconnections among parts of the entire system. In trans-disciplinary IS research, the central artifact is no longer the IT, but a collection of natural, human and social capital that interact within the biosphere. Finally, in order to conduct such work, scholars will draw upon reference disciplines outside of IS in addition to the field's traditional reference disciplines, and will incorporate and synthesize work from a diverse range of other disciplines, including ecology, environmental management, conservation biology, and the natural sciences.

Based these foundational issues, we define trans-disciplinary ISSR as an investigative process undertaken by IS scholars in collaboration with scholars from other disciplines and from practice, which involves joint definition of research problems, designs and outcomes, integration of systems, target and transformational knowledge, and synthesis of different disciplinary perspectives, with the goal of addressing practical concerns regarding biosphere sustainability. Thus, ISSR must incorporate concepts, models, practices, and policies from multiple stakeholders to build a joint vision of environmental sustainability.

A Trans-disciplinary Framework for IS Sustainability Research

To develop a trans-disciplinary research framework for ISSR, we return to the questions posed by von Krogh and Spaeth (2007) which emphasize society, interaction with a broad set of phenomena including new and divergent phenomena, and identification of relevant scientific discourse. These broad characteristics are well captured in a modified version of the biosphere sustainability ladder (Figure 1) proposed by Herman Daly (1973).



This representation specifies the whole system as composed of four interconnected domains of interest: the natural capital which provides the fundamental means and landscape for all human activity, the intermediate means and intermediate ends of such activity, and the ultimate purpose(s) of human activity. The subject of each level in this ladder is often framed by the discourses of different disciplines, such as environmental science, ecology and atmospheric science at the base, which focus on characteristics of the natural world; technology, organizations, energy production/consumption, and economics which connect intermediate means and intermediate ends; and ethics, values, policy, and sociology which focus on the status and ultimate ends of human existence. This visualization of the relationships among fundamental means, intermediate human activities, and ultimate ends provides insights into the potential for trans-disciplinary approaches to biosphere sustainability research. The levels are not independent domains but rather strongly coupled parts of an interdependent system. ISSR entails the study of the connections and information flows between these levels to better understand the interactions. As suggested in Table 3, trans-disciplinary approaches to sustainability will be facilitated by identification of the contributions and interactions between information systems, organizations and institutions which support business and the economy, societal goals and policies, and the salient areas of biological and geophysical science (Bectel 1986; von Krogh and Spaeth 2007).

In the center of the ladder, the transformation of intermediate means to intermediate ends represents the domain of business and economy and constitutes the majority of IS sustainability research to date. As indicated in Figure 1, intermediate means include human and social capital, as represented by indicators such as technological innovations, trained labor, and efficient production facilities. Intermediate ends are reflected in the collective social capital indicated by GDP, labor productivity, social mobility, safety, health, education, and standard of living. IS research in this area focuses on the relationship between information systems and organizations as the means, and organizational performance related to competitive advantage, financial return on investment, and environmental ‘friendliness’ as the ends. The principle motivation for research is to use information systems to achieve organizational efficiency through practices which are assumed to be less unsustainable. The areas of current research include energy informatics, sustainability portfolios, eco-goals, low impact waste disposal, and environmental management systems, and will result in organizational changes in the relationships between intermediate means and intermediate ends. However, these changes will only have uncertain and indirect effects on the fundamental means afforded by the natural capital, or on the ultimate goals of human and biosphere well-being.

In clearly identifying where current IS research is situated within the biosphere sustainability ladder, this framework also demonstrates that this middle ground comprises only a portion of the total human-environment system. Importantly, the indicators of success in modern society (e.g., stock market indices, Gross Domestic Product, return on investment) and many dependent variables in business-oriented IS research (e.g., system usage, IT adoption, alignment, IS success) treat these intermediate ends as the ultimate goal of human activity. This affects both individual and organizational attitudes and also drives the system toward constant growth, which no system can sustain (Meadows 1998).

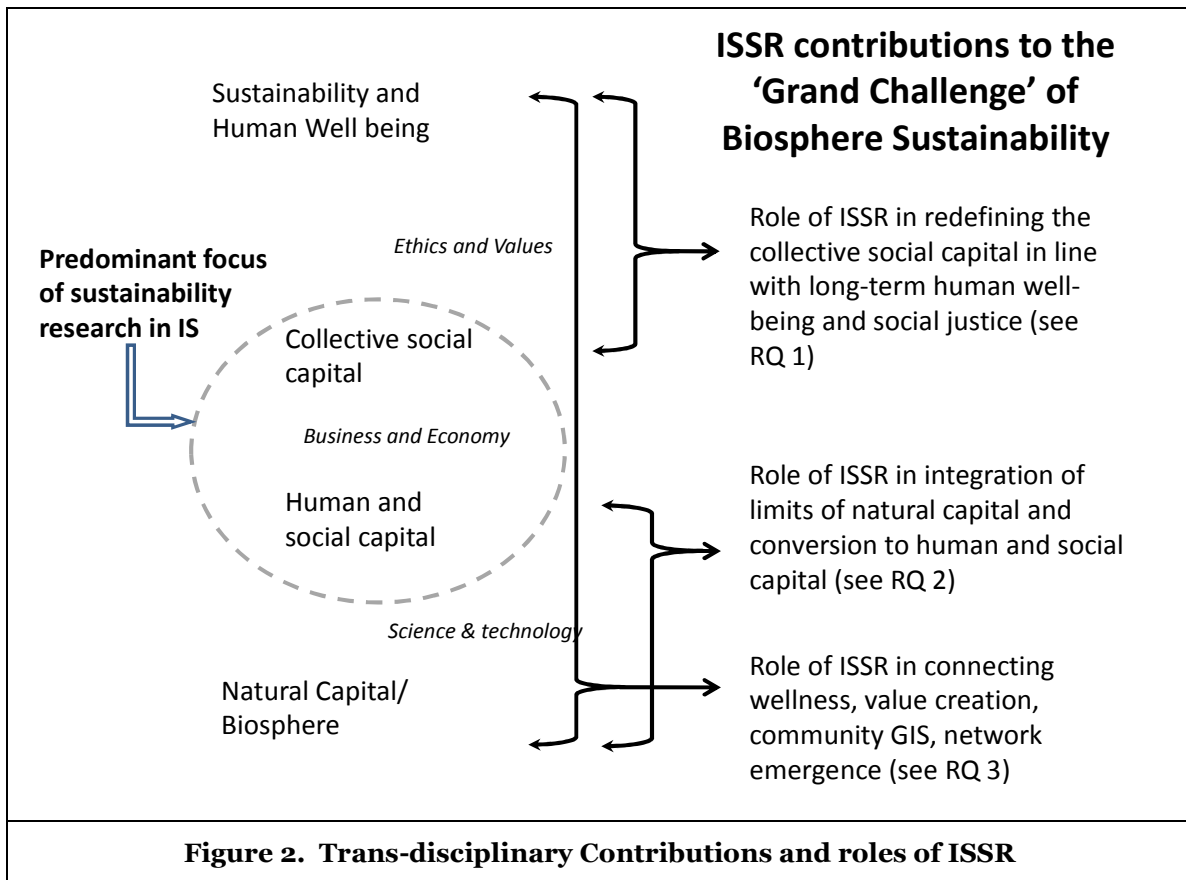
Thus, we propose that ISSR be extended toward both ends of the biosphere sustainability ladder to consider the potential contribution of IS-oriented research in the broader context. For example, little is understood on the potential role of IS in instantiating ethics and attachment of meaning to the biosphere or to increasing peoples’ understanding of the science underlying problems such as climate disruption, biodiversity loss, or finite resources. Additionally, significant research opportunities lie at the base of the ladder to elucidate the scientific relationships which couple the biosphere and artificial human and social capital.

A Proposed Trans-disciplinary Agenda

Based on this conceptualization of biosphere sustainability and in the spirit of addressing the grand challenge of sustainability, we propose key trans-disciplinary research domains represented by three broad research questions and illustrated in Figure 2. These are by no means exhaustive but suggest trans-disciplinary questions to which ISSR is uniquely suited to respond.

Extending IS Beyond the Bounds of Business and Economy

By virtue of being situated in the middle of the biosphere sustainability ladder, the domain of business and economy is connected to the societal domain of human well-being and to the fundamental means of natural capital. Thus, as shown in Figure 2, opportunities exist for IS to move beyond the boundaries of corporate organizations and to address the coupling of collective social capital to local and global well-being and a sustainable standard of living for a growing world population. This approach requires that researchers overcome the social world, the business/economy domain and the biosphere to understand the dynamics and long term behaviors of the system (Cronin 2008). For instance, a better understanding of the evolution of inequalities, labor conditions and toxic waste regulations enabled by outsourced manufacturing and waste disposal, access to health care and education, and the formation and maintenance of supporting institutions is required to address the multitude of problems faced in developing countries and rural areas.



Emphasis on sustainable standards of living will require a re-evaluation of our definitions of prosperity (Jackson 2009) and equitable distribution of material goods, resources, and energy. In addition to supporting communication and coordination activities, ISSR can support the identification of groups with aligned interests, thus fostering large-scale political mobilization and social movements (Dourish 2010). For example, as communities grow, they are frequently at a loss to understand the impacts of building development, resource extraction, or waste disposal in their local areas. Information systems providing visualization for the spatial and temporal distribution of the impacts from community planning and development activities (Hovorka and Auerbach 2010; Rutledge et al. 2007) allow communities a greater voice into determining how their communities will be developed and sustained. Similar approaches could be used on a larger scale, such that spatial visualizations will be instrumental in understanding the scales at which people act upon, and in turn are acted upon, by the environment.

Additionally, networks of similar or different types of organizations can engage in collaborative system-thinking and organizational learning which enable systematic changes necessary for social justice, equitability, and biosphere sustainability (Senge et al. 2008). These may include determination of carbon costs in supply chains, the dispersal of waste products affecting distant areas, tracking of crime and corruption, and increasing access to medical and educational resources. Increased comprehension of human-biosphere relationships will lead to changes in the social logic of consumerism which flows from the business and economy domain. Thus, one broad trans-disciplinary research theme can be articulated as:

RQ1: How can information systems be applied to integrate sustainability, human wellness, and social justice with collective social capital within the finite limits of the biosphere?

A promising research direction with respect to this question relates to how our societies generate, distribute and consume electricity. Recognized as the greatest engineering achievement of the 20th century (Constable and Somerville 2003), electrification has been instrumental for industrial and economic development. However, as economic fortunes have increased with electrification, so too has the toll on the biosphere. The generation of electricity from fossil fuels is a major threat to biosphere sustainability. In this century, the deployment of information technologies and systems to create a smart electricity grid opens up possibilities for integrating artificial human and social capital, collective social capital, human well-being and sustainability. The evolution of the smart grid creates opportunities for society to reconsider the underlying values and ethics related to unconstrained growth and energy waste, the need for just and equitable global distribution of electricity resources, and the ultimate values associated with renewable energy. For instance, research in Japan found that efforts to achieve reductions in GHG emissions by switching to nuclear-power for electricity generation resulted in negative social and environmental impacts in terms of an unfair distribution of risks associated with radioactive materials (Kondoh 2009). In keeping with the trans-disciplinary nature of ISSR, IS researchers could engage with colleagues in other disciplines, such as engineering, renewable energy, environmental science, social justice and public policy, as well as with experts in industry, to conduct research that integrates considerations of human wellness, social justice and biosphere sustainability within the more traditional boundaries of organizations and economics.

Reconnecting Intermediate Means to Fundamental Means

A second important domain for ISSR exists at the lower portion of the biosphere sustainability ladder where fundamental means and intermediate means transact. The biodiversity of life at the genetic, species and ecosystem levels, and the ecosystem services humans depend upon, are increasingly at risk (Chapin et al. 2000). As ecosystem services become degraded, the costs for these services are shifted to the organizations and people who consume them (Daily 1997; Loomis et al. 2000). As an example, as logging degrades forest watersheds, the need for water filtration plants increases the cost of water to users (Salzman 2005).

The natural environment and ecosystems are integral to the biospheric system. There is a need to both cognitively and pragmatically reconnect fundamental means with intermediate means. In the Anthropocene, human enterprises directly influence land transformation, biotic additions and losses, and changes in global biogeochemistry, which drive climate change, loss of biodiversity, and ecosystem service degradation (Vitousek et al. 1997). Although global biodiversity challenges are well-recognized, most biodiversity indicators show declines, even though conservation responses are on the increase (Butchart et al. 2010). Ecosystem management, and the geographic and temporal extent of human impact on the biosphere, need to be better understood and communicated to increase recognition of their importance to society (Walker 2002), especially as humans increasingly must take responsibility in a stewardship role of the Earth system (Steffan et al. 2011). In response, ecologists, land managers, and conservationists have implemented adaptive management frameworks which incorporate natural variance and non-linearity in emerging environmental threats, management interventions, and outcomes (Salafsky et al. 2010) and encourage knowledge creation as a result of environmental interventions. These are roles for which multi-criteria decision support systems (Janssen 1992) and visualization systems are well suited (Dow and Downing 2009; Ellis and Ramankutty 2008).

When considering the state of fundamental means, trans-disciplinary research also recognizes that comprehensive knowledge results from the combination of different disciplines and domains. The

information within each domain must be synthesized. The business and economy domain makes decisions which affect the natural world and the dynamics in the natural world feed-back to the business-economy domain. Therefore, another grand challenge research question for ISSR is:

RQ2: How can information systems aid decision-making such that ecosystem services and biodiversity are maintained and sustainable resource use occurs during conversion of fundamental means into intermediate means?

An example of research in this area is the development of decision support systems for conservation prioritization and adaptive management of biodiversity. This adaptive management practice enables organizational, political and regulatory responses to react to changes in the natural capital and the biosphere, rather than assuming that a given set of innovations or businesses processes will remain effective in a dynamic environment. Thus, ISSR approaches will be critical in creating, monitoring and evaluating biosphere systems at a collective scale and will enable the development of stronger and healthier linkages between fundamental and intermediate means.

Coupling Human Well-being and Biosphere Sustainability

The third research domain of ISSR brings together both ends of the biosphere sustainability ladder. The ultimate ends of all human activity have been under debate for centuries and will continue to be equivocal. But as the goal of ISSR is biosphere sustainability, indicators of the ultimate ends, human well-being, serve to guide human activity in the domain of business and economy. One factor in the current unsustainable rate of resource use and waste production is the reliance on indicators of intermediate ends (e.g., Gross Domestic Product, Return on Investment) as the measure of societal success. But accumulation of social and material capital, as an end in itself, is not sustainability. Alternative societal success indicators such as the Gross National Happiness Index (Di Tella and MacCulloch 2005) and the Human Development Index (United Nations 2011a), recognize that human development must include greater opportunity and choice (Sagar and Najam 1998) and prosperity in different forms (Jackson 2009). These types of indicators can serve to guide the use of natural capital to provide an acceptable and equitable standard of living for the global population.

That access to natural environments and the ecosystem services they provide is coupled with human well-being is well understood. Clarifying, measuring and monitoring indicators of human well-being will help determine the sufficiency with which needs are met relative to the needs of the biosphere and its myriad of inhabitants. Combined with current research aimed at increasing the efficiency with which natural capital is consumed, it may become possible to modify human attitudes and behavior to create sustainable interactions with the environment so that the needs of both can be met. A research question which contributes to the grand challenge of sustainability in this domain can be stated as:

RQ3: How can information systems engage individuals in understanding salient scientific information such that a healthy local and global biosphere becomes a priority?

Achieving sustainability requires the interest and actions of individual actors and groups. ISSR focused on the creation, maintenance, and analysis of social networks which support environmental awareness and social/political mobilization can achieve attitudinal, behavioral, and regulatory changes. The application of spatial analysis and location-enabled data will be transformational in our understanding of how we, as a species, inhabit the world, and our impacts on ecosystems services and environmental health (Dow and Downing 2009; Lea et al. 2008). Organizations and governments can be influenced by their customers and voters. But individuals do not prioritize the health of the biosphere when they do not understand or believe the scientific data. Species extinctions do not take priority when businesses present stark choices between jobs and animals. Although a majority of respondents in a US climate change survey indicate that climate change, environmental degradation, and loss of biodiversity are high priority problems (Leiserowitz et al. 2011) there is also evidence that the percentage of Americans who believe in climate change is declining (Kohut 2009).

Groups such as the Center for Ecological Analysis and Synthesis² have produced research on the influence of social networks on environmental attitudes, the integration of social science and conservation, and the

² www.nceas.ucsb.edu/products

relationship between social responsibility and ecology. Multiple types of global environmental assessments (e.g., Intergovernmental Panel on Climate Change, Global Biodiversity Assessment) are under development and serve to disperse scientific knowledge and guide policy decisions (Mitchell et al. 2006) across a broad range of sustainability problems and solutions. It is likely that these efforts could be further enhanced and accelerated through the active participation of IS researchers and trans-disciplinary perspectives.

Discussion

Biosphere sustainability is a grand challenge, requiring a paradigm shift in our view of the problems and potential solutions. Despite the genuine attempts of organizations, many environmental and social initiatives are executed in isolation and do not demonstrate significant contribution towards long term sustainability. Implementation of practices intended to address environmental problems has proven problematic, because in many cases impact indicators have been oversimplified relative to other indicators and frameworks, such as those used in the field of social impact assessment (Vanclay 2002). Even if the ecological footprints of some individual organizations are being reduced, the collective ecological footprint of organizations and of human activity is still increasing (Gray and Milne 2002), a classic example of a tragedy of the commons (Hardin 1968; Meadows 2008).

The IS research community has significant potential to offer in the domain of sustainability, but the work is constrained by underlying assumptions that do not recognize the incompatibility of continuing unconstrained growth. The current trajectory of work in the field does not leverage the accumulated knowledge and expertise in other disciplines, such as ecology, the bio-geophysical disciplines, and social impact analysis. Despite calls for trans-disciplinary research in IS, there have been few empirical studies in the mainstream literature which extend beyond the confines of the management and business literature. By not seeking out and synthesizing knowledge and research methods from other disciplines and by focusing on research on the business community, the IS discipline limits its potential contributions to the grand challenges of sustainability. Trans-disciplinary research requires a common language, collaborative learning, acceptance of trade-offs, and a joint vision which can increase empirical knowledge and affect pragmatic, normative and value levels of action (Cronin 2008; Max-Neef 2004).

This paper set forth three main contributions. First we illuminate and challenge traditional views of sustainable development and propose an alternative view in which biosphere sustainability is the focal objective. Identifying and questioning our underlying models and assumptions is a necessary process for enriching our comprehension of sustainability and conducting research that is innovative and meaningful. Second, based on a review of the extant IS literature, this paper develops a broader trans-disciplinary approach to IS sustainability research - one in which researchers transcend disciplinary boundaries and integrate research and practice. Third, we propose a broad research agenda based on the biosphere sustainability ladder, which illustrates connections between fundamental means, intermediate ends, and the ultimate ends. We have identified and discussed three main areas for trans-disciplinary ISSR: extending IS beyond the bounds of business and economy; reconnecting intermediate means to fundamental means; and coupling human well-being and sustainability. By taking a new approach, IS research can create entry points for research by integrating across levels for biosphere sustainability research.

Despite these contributions, there are limitations of this work. Most significantly, the literature review of trans-disciplinary research as well as the existing sustainability research was limited to the mainstream publications in the field. We recognize that this review might therefore not account for IS-oriented trans-disciplinary research published in other disciplinary journals or other IS journals or conferences. Also, for the IS literature review we chose to focus specifically on publications using the term 'trans-disciplinary' rather than including related terms such as multi-disciplinary, cross-disciplinary or inter-disciplinary. It is possible that research of a trans-disciplinary nature might use these other terms; however, our overall sense is that the conclusions and framework presented in this paper are unlikely to be much different had these been included.

For the IS research community to engage in ISSR, integrating knowledge from other disciplines and transcending boundaries between organizations, the sciences, politics, and practice is critical. Recognizing that research which crosses disciplinary boundaries is perilous and often difficult to publish (Campbell 1969), as a start, we have provided a working definition of trans-disciplinary ISSR and potential research

directions. Next steps would involve providing training for doctoral students and current researchers in addressing the challenges of trans-disciplinary research, support from IS publication outlets, and an increasing competency in evaluating trans-disciplinary research. Several key criteria should be considered. Does the research: reflect an integration across multiple diverse disciplines; clearly articulate interfaces to other areas; have in place structures and methods to support and reinforce these interfaces in agreement with experts from the different disciplines (Tappeiner et al. 2007); and adhere to a process where research and practice come together to expand theoretical knowledge and real-world problem solving (Espinoza-Tenorio et al. 2010)? With practice and experience, these criteria can be refined and exemplars developed to further establish expectations and standards.

As IS researchers who seek to address to the grand challenge of biosphere sustainability, it is critical that we not merely export the existing concepts of information systems into other domains without careful reflection and appreciation of context. Senge et al.'s (2008) challenge to ground paradigmatic change in new ways of thinking and perceiving requires that IS researchers not recapitulate the business *status quo* which, in part, created the current environmental problems and unsustainable practices. By explicitly recognizing that peoples' actions, the impacts of organizations, and the environment are intertwined in a complex and evolving system, ISSR can expand and shape the ongoing debate and contribute to the changes in fundamental values, beliefs, and models that will be required for human participation in a sustainable biosphere.

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