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ISSUES AND OPINIONS

INFORMATION SYSTEMS INNOVATION FOR ENVIRONMENTAL SUSTAINABILITY[1]

By: **Nigel P. Melville**
Stephen M. Ross School of Business
University of Michigan
701 Tappan Street
Ann Arbor, MI 48109
U.S.A.
npmelv@umich.edu

Abstract

Human life is dependent upon the natural environment, which, most would agree, is rapidly degrading. Business enterprises are a dominant form of social organization and contribute to the worsening, and enhancement, of the natural environment. Scholars in the administrative sciences examine questions spanning organizations and the natural environment but have largely omitted the information systems perspective. We develop a research agenda on information systems innovation for environmental sustainability that demonstrates the critical role that IS can play in shaping beliefs about the environment, in enabling and transforming sustainable processes and practices in organizations, and in improving environmental and economic performance. The belief–action–outcome (BAO) framework and associated research agenda provide the basis for a new discourse on IS for environmental sustainability.

Keywords: Belief–action–outcome (BAO) framework, environment, environmental management system, green, information system, innovation, organization, sustainability

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Introduction

Deterioration of the natural environment poses risks and opportunities for business organizations. Some firms respond by adopting environmental management strategies. For example, Marks & Spencer committed to a five-year plan to reduce its greenhouse gas (GHG) emissions (Rose 2008), and Google installed a solar power facility at its U.S. headquarters. Environmental regulations impose additional constraints on business organizations, such as the European Union target of a 20 percent GHG emission reduction and 20 percent renewable energy use by 2020 (Barroso 2008). As evidence of worldwide environmental degradation mounts—melting glaciers, resource depletion, ocean acidification, deforestation, etc.—the pressure on organizations intensifies. Our principal thesis is that information systems research can make an important contribution to knowledge at the nexus of information, organizations, and the natural environment; to the development of innovative environmental strategies; to the creation and evaluation of systems that break new ground in environmental responsibility; and, ultimately, to the improvement of the natural environment.

The objective of this paper is to galvanize IS research on environmental sustainability. An encompassing definition of sustainability is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987, p. 43). This definition is related to the triple bottom line, a broad conceptualization of organizational performance comprising economic, environmental, and social dimensions (Kleindorfer et al. 2005; Porter and Kramer 2006). In this paper we focus on the environmental and economic dimensions of the triple bottom line. We thus define IS for environmental sustainability as IS-enabled organizational practices and processes that improve environmental and economic performance. We launch a new discourse on IS innovation for environmental sustainability by drawing upon the uniqueness of IS scholarship, which incorporates both behavioral science (search for truth) and design science (search for utility in designed artifacts) (Hevner et al. 2004).

Business researchers have studied the topic of environmental sustainability for decades. Operations researchers have examined the adoption of environmental quality standards (Corbett and Kirsch 2001), lean production and environmental performance (King and Lenox 2001), and sustainable supply chains (Klassen and Vachon 2003). Marketing researchers have examined consumer adoption of green products and the marketing of sustainable business initiatives (Belk et al. 1981, Collins et al. 2007). Business economists have analyzed regulatory mechanisms, such as voluntary programs that act as information diffusion programs (Lyon and Maxwell 2007). Management researchers have examined the antecedents of environmentally destructive (Bazerman and Hoffman 1999) and environmentally beneficial (Bansal and Roth 2000) activities and have published research critiques (Gladwin 1993; Shrivastava 1994).

In contrast, few studies of environmental sustainability incorporate the information systems perspective. Organizational adoption of sustainability strategies necessitates new data regarding environmental impacts, new information about causes and effects, and knowledge sharing about what works, what doesn't, and why. For example, Chevron responded to the need for improved environmental risk management by developing a decision support system to systematize cost-benefit analysis (Reinhardt et al. 1999). Similarly, DuPont employed knowledge management systems for pollution remediation and prevention, creating a tension between organizational privacy and the need to pool environmental information among industry participants (Carberry 2001). Many firms have implemented environmental management systems (EMS), management programs requiring information systems to monitor, evaluate, improve, and communicate environmental performance—including information baselines on inputs (energy, water, materials, etc.) and outputs (waste, emissions, etc.) (EPA 1996).

Looking to the future, increased energy costs and the transition to renewable energy sources will necessitate, for example, an understanding of the design of innovative information systems for energy monitoring, understanding of the antecedents of use of energy optimization systems, and understanding of the impact of demand response on energy markets and peak load requirements.[2] Such issues at the intersection of information, organizations, and the natural environment are precisely the types of problems for which IS researchers are uniquely equipped to analyze. Moreover, the locus of IS scholarship spanning individuals, groups, organizations, and markets—as well as design—(Sidorova et al. 2008) is congruent with the requirements of complex sustainability problems involving the micro (individual beliefs and actions) and macro (organizational sustainability programs and their economic and environmental outcomes). There is much that IS scholarship can contribute to environmental sustainability.

The plan of the paper is as follows. We begin by summarizing the results of a literature search for environmental sustainability articles published in leading IS and operations research journals. Next, we adapt Coleman's (1986) micro–macro model to develop the belief–action–outcome (BAO) conceptual framework that links macro-level constructs (society, natural environment, organizations) with micro-level constructs (individuals). We then develop a set of research questions associated with philosophical perspectives and theory; research methodology and data sources; and sustainability phenomena. We conclude by summarizing findings and discussing implications for research and practice.

Prior Research

To ground a "green" IS agenda, a literature search of sustainability articles was conducted in five leading IS and operations research journals for the eight-year period 2000–2007, yielding 35 articles (Table 1).[3] Most articles (34) were

[2]As an example, Google has developed PowerMeter to manage information from smart meters and energy management devices and display it on the iGoogle homepage (http://www.google.org/powermeter/howitworks.html, accessed on 5/2/2009).

[3]IS journals based on the list of top journals adopted by the Association for Information Systems in 2008 and available for the entire 8-year period: *European Journal of Information Systems* (EJIS), *Information Systems Journal* (ISJ), *Information Systems Research* (ISR), *Journal of MIS* (JMIS), and *MIS Quarterly* (MISQ). Operations journals include *Journal of Operations Management* (JOM), *Management Science* (MS), *Manufacturing and Service Operations Management* (MSOM), *Operations Research* (OR), and *Production and Operations Management* (POM). *Business Source Complete* was employed, with keywords including environment, environmental management practices, environmental sustainability, sustainable business, green business, green supply chain, and ISO 14001. We searched citations of identified articles to expand the list. We also performed manual checks of each article to confirm its sustainability content.

Table 1. Published Articles on Environmental Sustainability

	YEAR								
	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**Total**
IS Journals									
EJIS									0
ISJ				1					1
ISR									0
JMIS									0
MISQ									0
OR Journals									
JOM				1	1			6*	8
MS	1	2	1		1		1		6
MSOM							1		1
OR									0
POM		9*		7*	1	1		1	19
Total	**1**	**11**	**1**	**9**	**3**	**1**	**2**	**7**	**35**

Note: Empty cells indicate zero studies. *Special issue or focus on environmental sustainability.

published in operations research journals, led by *POM* with 19. Only one article was published in an IS journal (*ISJ*). Analysis of a larger set of economics, business, and management articles indicates a five-fold increase in the percentage of sustainability-themed articles from 1990 through 2005 (Linton et al. 2007).

Examination of the content of the articles reveals three principal topics: antecedents, performance, and supply chains (Appendix A). Studies in the first research topic examine factors that promote or inhibit the adoption of sustainable business practices, such as how the presence of ISO 9000 (quality management standards) explains the adoption of ISO 14000 (environmental management standards) (Corbett and Kirsch 2001; Vastag 2004). Studies in the second research topic examine the association between sustainability practices and organizational and environmental performance outcomes (Montabon et al. 2007; Zhu and Sarkis 2004). The third research topic focuses on supply chains and is distinctive for its interorganizational focus (Mazhar et al. 2005; Quak and Koster 2007). Other research streams examine green product development (Chen 2001; Noori and Chen 2003), lean manufacturing (Rothenberg et al. 2001), and regulation (Barrieu and Sinclair-Desgagne 2006; Subramanian et al. 2007). The information systems perspective was examined in but a single research study, development of a collaborative reporting system for communicating stakeholder positions on genetically modified food (Heng and de Moor 2003). In sum, the IS perspective in research on environmental sustainability is nascent, despite the critical role of information systems in improving the natural environment and addressing climate change (Boudreau et al. 2007; Climate Group 2008; Erdmann et al. 2004; Farrell and Oppenheim 2008; Richards et al. 2001).

Conceptual Framework

Next we articulate a conceptual framework for framing research issues at the intersection of information systems, organizations, and environmental sustainability, beginning with an explication of the requirements for such a framework.

Requirements

Compatible with IS Research Diversity

The intellectual core of the IS discipline contains five research areas (IT and organizations, IT and markets, IT and groups, IT and individuals, IS development), each of which spans numerous research themes (Sidorova et al. 2008).[4] For

[4]An information system (IS) is a combination of people, processes, and technologies that enables the processing of digitized information. Information technology (IT) refers to the information technologies that comprise the

example, IT and organizations includes 22 themes including IS planning, IT for competitive advantage, business process reengineering, value of IT investments, IT outsourcing, organizational culture, real options and option pricing, networks, and knowledge management. Likewise, IT and individuals (12 themes) includes such diverse themes as individual technology acceptance, user satisfaction, training, service quality, and trust. Diversity is a strength of the IS field (Robey 2003); therefore, a conceptual framework for issues spanning IS and environmental sustainability must encompass the full range of analysis levels, theoretical perspectives, and research methodologies.

Incorporation of Distinctiveness of Environmental Context

Environmental sustainability is distinctive in scope, complexity, and urgency. First, the sustainability context extends the social, organizational, and individual domains to include the natural environment: air, land, water, etc. This broadened scope has several implications, such as incorporation of environmental performance and the need for new research methodologies and metrics. Second, sustainability phenomena are complex and multilayered, often characterized by uncertain interdependencies and nonlinearities. One implication is the existence of alternative frames for the problem, including the rational (economic considerations such as productivity and profitability), natural (environmental sustainability, including preservation of natural resources and mitigation of climate change), and humanist (personal satisfaction and social needs such as fair trade practices and human rights) (Elkington 1994).

The role of information and information systems may be interpreted differently depending on how the problem is framed. For example, if the problem is framed in economic terms, IS may be viewed as a means by which energy productivity (quotient of output and amount of energy used) is increased. If the problem is viewed in ecological terms, IS might be framed in terms of how online social networking reduces greenhouse gas emissions, or, how data centers increase greenhouse gas emissions. Another implication of complexity is the need for research methodologies that account for uncertainty and feedback, such as system dynamics (Sterman 2001). Last, environmental sustainability problems are urgent, given mounting climate change evidence and observable environmental degradation. A compelling conceptual framework for IS research on environmental sustainability will be grounded in scientific rigor and provide insights that are immediately relevant to practice, including questions of what, why, and how concerning the role of information and information systems (Straub and Ang 2008). In sum, the environmental sustainability research context is distinctive in scope, complexity, and urgency, requiring IS researchers to extend epistemological horizons.

technological foundation of information systems. We use the two terms consistent with these definitions, except when referring to the research of others, in which case we use their terms (to avoid confusion).

Belief–Action–Outcome (BAO) Conceptual Framework

Coleman's Micro–Macro Model

Problems involving information systems and environmental sustainability involve human behavior and the broader social, organizational, and environmental contexts. Review of the IS and operations literatures and examination of other business literatures reveals three classes of sustainability phenomena: (1) how cognitive states about sustainability (beliefs, opportunities, etc.) emerge; (2) actions of organizations and individuals regarding sustainability practices and processes; and (3) environmental and financial performance outcomes. Taken together, the three classes of phenomena comprise micro and macro issues. Coleman's (1986, 1994) model of micro–macro relations provides the foundation for our conceptual framework.

The model underscores the mediating role of individuals in linking macro-level variables such as social structure and the behavior of the social system (Figure 1). Three types of relations are included: (1) macro-level variables such as social structure affect the psychic states (beliefs, desires, opportunities, etc.) of individuals (link 1); (2) psychic states affect individual action (link 2); and (3) combined individual action affects macro-level variables such as the behavior of the social system (link 3). The social system construct refers to both social and natural systems (Berkes and Folke 2000) and contains individual and corporate actors (Coleman 1986). Consider the example of technological determinism (Figure 1b). Individuals observe the transformation of social and organizational life related to digitization of everyday activities from social networking to booking an airline flight, which leads to a belief that IS can solve all human problems. This in turn leads to profligate use of natural resources (IS will solve the depletion problem), which leads to depletion of natural resources (e.g., declining fossil fuel stocks).

Coleman's (1986) model has been widely applied, refined, and extended in the sociology (Hedstrom and Swedberg 1998;

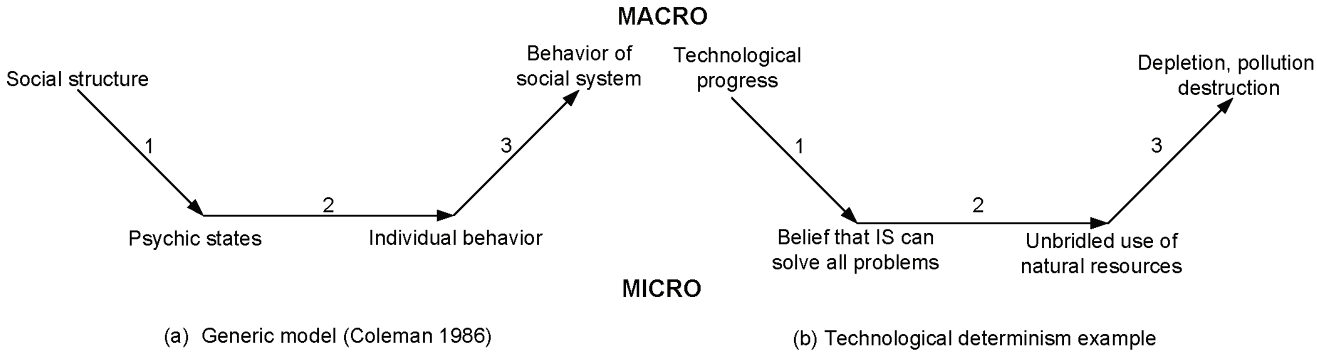

Figure 1. Coleman's Model of Social and Individual Relations and Information Systems Example

Udehn 2001) and organizational literatures, for example, to examine individual perspectives on absorptive capacity and knowledge transfer (Minbaeva et al. 2007) and micro-foundations of strategic management and organizational analysis (Felin and Foss 2006). It has also been applied in the IS literature to explicate levels of analysis in theorizing (Markus and Robey 1988).

Belief–Action–Outcome Framework for IS and Sustainability

We develop the belief–action–outcome (BAO) framework by adapting Coleman's model to explicitly include the social and organizational contexts (see Felin and Foss 2005; Hedstrom 2005). We introduce an additional antecedent, organizational structure, as well as an additional outcome, behavior of organization (Figure 2). In this way, we account for dual socialization (individual psychic states are shaped by social structure (link 1) and organizational structure (link 1')) and dual outcomes (combined individual action may improve organizational (link 3') and environmental (link 3) performance). Regarding belief formation, tensions may arise within individuals due to conflicts between organizational values (e.g., short-term profit motive) and personal values which are shaped by society (e.g., going green to save the planet).[5] Regarding outcomes, delineation of financial and environmental performance underscores the importance of both dimensions of performance; an environmental management program that reduces costs but does not measurably improve the environment is of dubious environmental value. The final extension is to include dashed lines linking four macro–macro states, allowing for research approaches that assume away differences in individual human behavior and treat organizations as collections of homogenous agents (links 4, 4', 5, 5'). Enhanced understanding of underlying causal mechanisms of individual links (e.g., link 1) as well as multiple links (e.g., how society influences individual action within organizations) is a rich source of future research on IS for environmental sustainability, as explicated below.[6]

In sum, the BAO framework provides a way of framing research questions intersecting information systems and environmental sustainability in organizations, is compatible with IS research diversity, and subsumes macro and micro perspectives found in the scholarly and popular literature (Erdmann et al. 2004; Farrell and Oppenheim 2008; Romm 2002).

An example in the popular literature is the *Smart 2020* report, which assesses the enabling effect of IS by estimating greenhouse gas reduction by areas of impact (transport, building, power, industry) (Climate Group 2008). However, the report says little about the underlying micro processes by which such change comes about, such as how employees learn about sustainability issues, how managers develop and implement

[5] Link 2 subsumes individual action occurring within and outside business organizations. Societal and organizational influences shape individual behavior within and outside the organization. We thank an anonymous reviewer for underscoring this point.

[6] We thank an anonymous reviewer for this line of reasoning. All sets of links (including bi-directional) in the BAO framework provide possible research directions. Figure 2 is a starting point for framing and analyzing the various interrelationships between micro- and macro-level variables pertinent to the context of IS for sustainability.

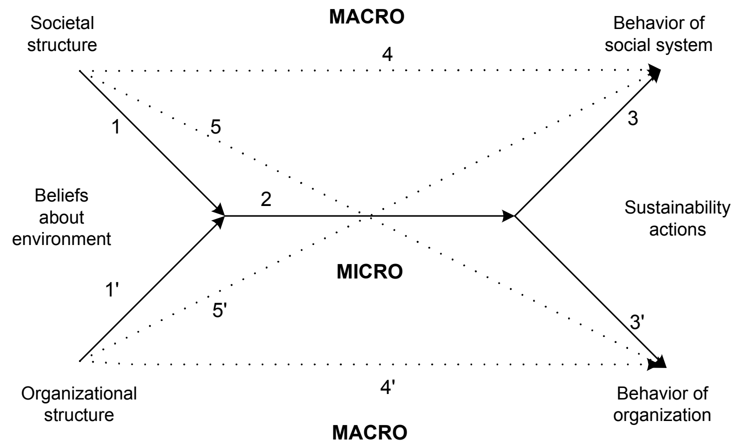

Figure 2. Belief–Action–Outcome (BAO) Framework for IS Research on Sustainability

Table 2. BAO Framework Terminology

	Belief Formation	Action Formation	Outcome
Description	How psychic states (beliefs, desires, opportunities, etc.) about the natural environment are formed.	How psychic states about the natural environment translate to actions.	How sustainability actions affect social and organizational systems. How macro states affect behavior of society and organizations.
Analysis Level	Macro–micro	Micro–micro	Micro–macro (links 3 and 3'). Macro–macro (links 4, 4', 5, and 5').
Constructs	**Societal structure**: Cultural or normative patterns that define expectations of agents about each other's behavior and that organize enduring interrelationships.† **Organizational structure**: Ways in which an organization divides its labor into distinct tasks and achieves coordination among them.‡ **Psychic state**: Beliefs, desires, opportunities, etc.	**Action**: Something done by an individual, such as adoption of an information system to improve organizational recycling or facilitate ride sharing.	**Behavior of society**: Functioning of society and natural environment (includes performance). **Behavior of organization**: Functioning of organization (includes performance).
Example Studies	Integrated assessment using a designed information system changed individual beliefs about risks of climate change (Schlumpf et al. 2001).	Belief that reducing greenhouse gas emissions is critical to sustainability leads to adoption of social networking site encouraging energy conservation (Bottrill 2007).	IT investment in services and most manufacturing sectors increases electricity demand, with implications for greenhouse gas emissions (Cho et al. 2007).
Example Theories	Contingency theory. Information processing theory. Media richness theory. Social presence theory. Stakeholder theory.	Game theory. Social cognitive theory. Technology acceptance model. Theory of planned behavior. Theory of reasoned action.	Absorptive capacity. Dynamic capability theory. Production theory. Resource-based theory. Systems theory.

†Adapted from Lopez and Scott (2000).
‡See Mintzberg (1979).

effective action plans involving information and IS, what types of new information are required, how such information is used, and how new information systems are designed. The BAO framework, by incorporating micro and macro levels, provides an encompassing approach to researching sustainability issues.

Finally, the framework is consistent with the study of dynamic change processes as well as static cross-sectional analysis. For example, the adoption of an environmental management system (EMS) incorporating an online social network with the goal of engaging employees, improving environmental performance, and reducing costs might be viewed as an organizational change process involving belief formation (links 1, 1'), sustainability actions (link 2), and environmental (link 3) and organizational performance (link 3') outcomes . In contrast, a survey of organizational use of IS for sustainability and perceived environmental performance impacts might focus entirely on the macro–macro (link 5').

Research Issues

We use the BAO framework to develop an initial research agenda on IS for environmental sustainability comprising 10 research questions spanning philosophical perspectives and theory, research methods and data sources, and sustainability phenomena.

Philosophical Perspective and Theory

Philosophical Perspective

> **Research Question 1: How can different philosophical perspectives—positivist, interpretive, critical, and design—be applied to complex problems involving information systems, organizations, and the natural environment?**

Four principal philosophical perspectives are employed in IS research: positivist, interpretive, critical, and design. A large proportion of IS research follows the *positivist philosophy* in which it is assumed that the researcher can observe objective reality, at least to a certain extent (Straub et al. 2005), and theoretical constructs can be validly measured (Mingers 2001; Orlikowski and Baroudi 1991). Positivism contributes to what is known, for example, by rejecting null hypotheses of no significant difference between quantities of interest. However, despite its prominence, positivism is not without limitations. Removing an observation from its context may distort meaning and cast doubt on research inferences (Gephart 1999). Tacit ideologies and beliefs may bias research topic selection and research findings, which could lead to a dearth of research examining unanticipated outcomes. According to the *interpretive philosophy* organizational life is socially constructed—economic considerations being secondary. The focus is on exploration of the meaning of contexts and interrelationships within organizations (Berger and Luckmann 1966; Klein and Myers 1999; Van Maanen 1988). In contrast, IS research employing the *critical philosophy* examines the processes by which individuals use IS to enhance their own personal power and silence alternative views (Hirschheim and Klein 1994; Ngwenyama and Lee 1997). The critical philosophy focuses on tension and struggle, rather than consensus and harmony. Finally, the *design philosophy* is a problem-solving perspective to knowledge creation in which IS innovations to solve organizational problems are developed and evaluated (Hevner et al. 2004). Design science researchers are concerned with the design process and the innovation outcome.

Each philosophical perspective provides a unique and valuable perspective for IS research on environmental sustainability. The core construct of environmental sustainability involves interpretation as to how it is defined and judgment as to how it ought to be defined—eco-efficiency, that is, increasing output with fewer natural resources consumed, improving the health of planet earth, reducing greenhouse gases, etc. Researchers tend to adopt the definition that supports their goals and objectives or those of important stakeholders (Welford 1998), and there is no reason why IS researchers will not behave similarly. One potential result is that IS research could be biased toward the objectives of managers or CIOs (Figure 2, links 3' and 4') rather than the natural environment (Figure 2, links 3 and 4) (Ahlstrom et al. 2007).[7] The critical perspective might be employed to examine the existence, range, sources of, and implications of such biases. In addition, the critical perspective might illuminate how information systems subvert sustainability and expose contradictions between stated goals and actual organizational practices.

The interpretive philosophy might inform whether, to what extent, and how the concept of sustainability is socially created, and the role of information and information systems

[7]An illustration of this phenomenon is that magazines such as *CIO* and *InformationWeek* tend to frame "green computing" as the energy efficiency of servers, which is directly tied to the performance metrics of stakeholder IS managers.

therein. As an illustration, IS researchers might question assumptions about the role of decision support systems as tools enabling sustainability (Sen et al. 2000; Shaft et al. 2002) versus mechanisms by which reality about sustainability is created within organizations.

Last, design research is essential to developing innovative IS-enabled solutions to environmental problems and evaluating their effectiveness. In sum, given the complexity of environmental sustainability as a research context, we advocate a multi-theoretic and pluralistic (Mingers 2001) approach to the use of philosophical perspectives within IS research on environmental sustainability.

Theory

> **Research Question 2: How can different theories be applied to complex problems involving information systems, organizations, and the natural environment?**[8]

The BAO framework encompasses environmental sustainability issues spanning diverse contexts, theoretical constructs, and analysis levels. Different theories are applicable to different phenomena (Table 2), but it is unclear which theories are appropriate for analyzing particular research questions. IS research employs theories developed within the field and theories from other fields such as psychology, economics, and sociology (Lee et al. 2004, Lim et al. 2009). The diverse theory base of IS scholarship is thus an advantage in explicating and analyzing the diverse phenomena represented in the BAO framework.

Research Methodology and Data Sources

Following is an illustration of how a few, selected research methodologies and data sources can be useful for studying IS for environmental sustainability.

Research Methodology

> **Research Question 3: How can different research methodologies, such as life cycle analysis and integrated assessment, be applied to examine complex problems involving information systems, organizations, and the natural environment?**

Life Cycle Assessment: Life cycle assessment (LCA) is a method of evaluating the deleterious impacts of products and services on the environment, which can be viewed through the lens of the BAO framework as the link between how society and organizations shape beliefs about green products (links 1 and 1'), the actions that employees take to develop green products (link 2), and impacts on the social system and environment (less waste—link 3) and the organization (increased sales—link 3'). LCA has been viewed as a means "for changing people's way of viewing and dealing with products and the environment" (Heiskanen 2000, p. 239). LCA comprises four steps: (1) set goals and scope of analysis; (2) model product or service system, including data collection, via an LCA inventory; (3) assess impacts of the product or service system on various measures (e.g., waste, greenhouse gas emissions, and energy consumption); and (4) interpret impact assessment, conduct sensitivity analysis, and create an aggregate impact metric by combining individual metrics (Fava 1994).[9]

Life cycle analysis has been employed to examine the oil, gas, and biotechnology industries (Matos and Hall 2007) and components of consumer products (Mazhar et al. 2005). Information systems and IT play two key roles in the context of LCA. The first is to enable life cycle analysis by capturing, storing, and processing pertinent data and information (Shaft et al. 1997). An example is open-source LCA software (Ciroth 2007), in which IS design research could play an important role. The second key role of IT is as a subject of life cycle analysis. LCA analysis of IT hardware is particularly salient given its ubiquity, rapid technological progress (short lifespan of IT hardware), and toxic elements used in IT hardware components. Both contexts—IS used to enable LCA analysis and LCA analysis of IT hardware—offer rich potential for IS researchers to improve knowledge about sustainability, with implications for scholarly research and management practice. However, we do not know how and to what extent IS researchers might fruitfully employ LCA.

Integrated Assessment and Integrated Assessment Modeling: As discussed earlier, the natural environment is complex, involving a system of natural and anthropogenic causes, effects, and feedback loops. For example, melting arctic ice reduces ice surface area which reflects less sunlight thereby amplifying global warming; this creates a positive feedback loop of melting more ice, which amplifies global warming, etc. Multiple scientific disciplines are involved in

[8]We thank an anonymous reviewer for motivating this research question.

[9]ISO 14040:2006 specifies LCA principles. ISO 14044:2006 specifies guidelines and requirements. See http://www.iso.org/iso/iso_14000_essentials for details (accessed on 4/6/2009).

Table 3. Research Questions

Domain	Research Question	BAO Link
Philosophical Perspective and Theory	**RQ1**: How can different philosophical perspectives—positivist, interpretive, critical, and design—be applied to complex problems involving information systems, organizations, and the natural environment? **RQ2**: How can different theories be applied to complex problems involving information systems, organizations, and the natural environment?	1, 1', 2, 3, 3', 4, 4', 5, 5'
Research Methodology and Data Sources	**RQ3**: How can different research methodologies, such as life cycle analysis and integrated assessment, be applied to examine complex problems involving information systems, organizations, and the natural environment? **RQ4**: How can different environmental metrics, such as CO_2 equivalent, be employed to assess the impact of IS on the natural environment?	1, 1', 2, 3, 3', 4, 4', 5, 5'
Phenomena		
Belief	**RQ5a**: What is the impact of information systems on beliefs about the natural environment and environmental sustainability? **RQ5b**: What design approaches are effective for developing information systems that influence human beliefs about the natural environment?	1, 1'
Action	**RQ6a**: How do the distinctive characteristics of the environmental sustainability context, such as values and altruism, affect intention to use and usage of information systems for environmental sustainability? **RQ6b**: What design approaches are effective for developing information systems that influence human actions about the natural environment?	2, 2'
Outcome	**RQ7**: What is the association between information systems and organizational and sustainability performance? **RQ8**: What is the association between information systems and supply chain performance from an efficiency and environmental perspective? **RQ9**: How can firms optimally invest in industry IS platforms intended to reduce negative externalities associated with the natural environment? **RQ10**: How can systems approaches shed light on organizational and environmental outcomes that result from the use of IS for environmental sustainability?	3, 3', 4, 4', 5, 5'

climate science, each with its own vocabulary and discourse. Compiling this diverse information into a coherent whole is the objective of integrated assessment, in which a variety of scientific information is synthesized for communicating knowledge about causes and effects of a specific phenomenon, for example, sustainability belief formation (links 1, 1') (Morgan and Dowlatabadi 1996; Pereira and Martin 1999).

Integrated assessment models are defined as "models that combine knowledge from multiple disciplines, with the aim of shedding light on policy questions" (Tol 2006, p. 2). Integrated assessment models have been used, for example, to examine the costs and benefits of global warming in a dynamic integrated climate–economy model (DICE) using constrained maximization (Nordhaus 1993) and to explore general equilibrium models of ecologies (Tschirhart 2003).

Integrated assessment and modeling might be used by IS researchers to examine sustainability questions in several ways. Knowledge management researchers might examine questions related to the natural environment by using integrated assessment as a synthesis and communication approach. Given the potential for significant value creation in the sustainability domain, such knowledge management efforts are likely to have a higher chance of success (Massey et al. 2002). Design science researchers might develop specific design methods and practices yielding innovative information systems to address the specialized informational requirements of integrated assessment of environmental sustainability problems (Schlumpf et al. 2001). Integrated assessment models that involve energy-reducing IS such as transportation systems might be employed to extend existing approaches to estimating their beneficial impacts (Climate

Group 2008), for example, by including knowledge from climate science, organizations, and the IS discipline. Despite the potential of integrated assessment as a research approach, we do not know how or to what extent IS researchers might fruitfully employ it.

Environmental Data Sources and Metrics

> **Research Question 4: How can different environmental metrics, such as CO_2 equivalent, be employed to assess the impact of IS on the natural environment?**

Data Sources: A rich source of sustainability data for IS researchers and other scholars in the administrative sciences is provided by corporate sustainability reports (CSR). Although lacking a standard reporting format, they provide detailed overviews of quantitative and qualitative sustainability indicators, useful for analyzing environmental outcomes (link 3). In a review of CSRs from leading global corporations, Kolk (2004) finds an increase in reporting from 12 percent of firms in 1993 to 28 percent in 2002, raises questions about the veracity of the reports, and summarizes their content, including management systems and environmental performance indicators (water, energy, materials consumption, waste, emissions). Other sources of data include surveys of global corporations regarding their greenhouse gas emissions (e.g., the Carbon Disclosure Project) and country-level environmental indexes (e.g., Environmental Performance Index).[10] Finally, governmental agencies such as the U.S. Department of Energy provide detailed metrics of energy consumption and energy-related carbon emission (from petroleum, natural gas, coal, etc.) by industry and region.

Metrics: Sustainability metrics can be structured into three categories: renewable, nonrenewable, and pollution (Daly 1990). Each of these areas can provide data for IS studies. Given the salience of climate change, we focus on the emission of greenhouse gases (link 3). Carbon dioxide equivalent ($C0_2e$) is the base currency of global warming emissions measurement. Each gas that contributes to global warming has a carbon dioxide equivalent, and that weighting factor is used to convert it into a common metric. Carbon dioxide equivalent is used by many large, publicly held, multinational corporations based in North America (Hoffman 2006) and is fundamental in regulatory mechanisms such as the Chicago Climate Exchange and the European Union Emission Trading Scheme (ETS). IS researchers might employ $C0_2e$ (and related measures such as $C0_2e$/output, energy consumed, energy consumed/output) for various purposes, including life cycle assessment, macroeconomic studies of the association between IS and GHG emissions, and case studies of systems designed to enable $C0_2e$ measurement and the use of that information for internal and external purposes.

Sustainability Phenomena

IS and Beliefs about Environmental Sustainability

Following is an overview of behavioral and design issues pertaining to the role of IS in informing beliefs about the natural environment and environmental sustainability.

> **Research Question 5a: What is the impact of information systems on beliefs about the natural environment and environmental sustainability?**

IS and Belief Formation: Societal and organizational factors influence the beliefs, attitudes, and desires held by individuals about the environment (Figure 2, links 1 and 1'). With respect to society, cultural influences such as movies, political discourse, and family shape beliefs about the health of the planet as well as the impact of human behavior thereon, for example, anthropogenic climate change. Apropos organizational factors, recycling campaigns, corporate vision statements, and environmental management systems also influence individual beliefs about the environment. The role of information and IS in shaping attitudes is core:

> [A]t the heart of the environmental crisis are the critical issues of information acquisition and attitude formation, for it becomes clear that in the absence of information, one cannot formulate attitudes toward an issue, whether positive or negative in content (Dumont and Franjeska-Nicole 2008, p. 5).

Despite its importance, few quantitative empirical studies have directly examined the role of information systems in belief formation in the context of sustainability, although studies in marketing and ecology underscore the salience of how information is presented to ethical consumer groups (Shaw and Clarke 1999), suggest a tension between eco-label information and the larger societal context (Pedersen and Neergaard 2006), and identify the existence of confusing information about sustainability (Burgess et al. 1995).

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[10]See, respectively, http://www.cdproject.net and http://sedac.ciesin.columbia.edu/es/epi/ (accessed on 4/26/2009.)

Although they do not incorporate information systems directly, such studies help to frame the issues that IS researchers might investigate concerning information about the environment and its sustainability.

In recent years, design science and computer–human interaction researchers have explored the connection between how information is presented and how beliefs about the environment are formed. One approach is integrated assessment, as discussed in the previous section (Morgan and Dowlatabadi 1996; Pereira and Martin 1999). For example, researchers designed and developed an information system to provide residents with information about local dimensions of climate change, then conducted focus groups to assess how well the system improved judgment about anthropogenic climate change (Schlumpf et al. 2001). Requirements analysis for the IS included elements of form, functionality, and quality. A principal result of focus groups was improved understanding of the risk and uncertainty associated with climate change as well as enhanced discourse about climate change.

Another emerging area of research lies in the visualization of environmental information, such as fossil fuel use and the amount of plastic recycled: "Eco-visualization technology offers a new way to dynamically visualize invisible environmental data" (Holmes 2006, p. 2). Other potential research contexts include mobile phone sensors in London informing users about pollution levels and social networking web sites with information about climate change, given preliminary survey data suggesting a correlation between social network use and attitudes about the environment (Dumont and Franjeska-Nicole 2008).[11] There is some evidence from the cognitive science literature suggesting that such designed artifacts might be effective in informing individuals about the environment (Abrahamse et al. 2005; Seligman and Darley 1977). However, we know little about what works best, for whom, and under what circumstances.

> **Research Question 5b: What design approaches are effective for developing information systems that influence human beliefs about the natural environment?**

IS Design Issues for Belief Formation: Information systems may play an important role in shaping beliefs about the environment, whether moderating existing beliefs formed by organizations or society, or perhaps mediating them. However, it is unclear how best to design such systems. Complicating matters are ethical questions that arise concerning the messages that are being communicated, such as the potential for green washing, that is, disclosing false information, deliberately misleading, or failing to fully disclose all information regarding impacts on the environment. In this regard, sustainable interaction design includes perspectives on values, methods, and reasoning about the environmental impact of designed IS artifacts (Blevis 2007). To what extent does computer–human interaction in systems development (Zhang et al. 2005), design thinking (Brown 2008), or an artistic approach yield the most effective artifact (links 1 and 1')? There is a lack of knowledge regarding how to design such systems and design science research could shed light on these issues (Gregor and Jones 2007; Hevner et al. 2004; March and Smith 1995; Peffers et al. 2007).

IS and Individual Sustainability Actions

Following is an overview of behavioral and design issues pertaining to the role of IS in enabling and driving environmental sustainability actions.

> **Research Question 6a: How do the distinctive characteristics of the environmental sustainability context, such as values and altruism, affect intention to use and usage of information systems for environmental sustainability?**

IS and Action Formation: There is a large body of IS scholarship analyzing the antecedents of individual adoption of information systems. The technology acceptance model (TAM) has been widely employed (Davis 1989; Davis et al. 1989) and informs understanding of beliefs about the environment and actions based on those beliefs (Figure 2, link 2). TAM posits that intention to use and usage are explained by two factors: (1) perceived qualities of an information system that make it easy to use, and (2) its perceived usefulness in improving individual performance. Comprehensive review of the TAM model, common extensions, and its integration with the user satisfaction literature yields additional explanatory factors of information quality and system quality (Wixom and Todd 2005).

TAM is one of the most widely employed theories in IS research, due in part to its high predictive power (Devaraj et al. 2008).[12] TAM is rooted in the premise that the motivation of individuals to use information systems is for individual

[11] See http://www.dataclimates.com/project_escience/escience_maintext.html and http://www.makemesustainable.com, respectively (accessed on 4/13/2009).

[12] See Sharma and Yetton (2009) for a challenge to TAM predictibility.

(typically task-related) purposes—improves individual effectiveness, enhances ability to get more work done in less time, improves decision making, etc. Other factors not included in current TAM models may also play a role in shaping beliefs and attitudes about the outcomes of behaviors, as specified by expectancy-value theory (Fishbein and Azjen 1975).

In contrast to typical TAM contexts in which resources are private, the environment is a public resource, with implications for how users approach technological systems intended to enhance its sustainability. For example, consider a voluntary web-based system for promoting recycling practices introduced within an organization (see Bottrill 2007). In addition to ease of use and usability, a user's attitude about the need for recycling (perhaps rooted in socialization) may also represent an important predictor. This is different from typical contexts of IS use (e.g., for personal efficiency) in that there is a social welfare element at play in which users may display altruism. It is possible that such social beliefs and attitudes may overcome low ratings on traditional TAM antecedents and lead to high intention to use, analogous to the finding that enjoyment trumps usefulness in hedonic information systems (van der Heijden 2004). We do not know the extent to which current TAM theory may exclude important sustainability predictors of intention to use. Incorporation of such factors may enrich TAM by including both social (Figure 2, link 1) and organizational (Figure 2, link 1') antecedents to intention to use. This informs a fundamental question related to the TAM approach, which is, how do preexisting beliefs about the importance of the function enabled by the system (e.g., reducing plastic waste)—beyond its ease of use and usefulness—influence adoption? Moreover, how do preexisting beliefs about the environmental impact of using a particular information system influence adoption? Research examining the motivational factors for knowledge sharing in organizations, including monetary incentives, psychological factors such as self worth, and sociological factors such as fairness, points the way toward future research examining beliefs and perceptions concerning IS for sustainability (Bock et al. 2005).

> **Research Question 6b: What design approaches are effective for developing information systems that influence human actions about the natural environment?**

IS Design Issues for Action Formation: As with belief formation, there is growing interest within the IS design community in developing innovative information systems that change user behavior (link 2). In contrast to dashboards or public media installations that rely on sophisticated IS to provide general environmental information, action-inducing systems provide individualized information. One example is the use of online energy management systems that provide instant feedback on individual energy use (Hammerstrom 2007). Another example is mobile phones that track green transportation habits and display this information using simple graphics such as trees with the number of leaves denoting the greenness of transportation (Froehlich et al. 2009). Given the newness of these applications, it is not clear what would be most effective in terms of design methodologies.

IS and Outcomes of Individual and Organizational Sustainability Actions

The outcomes of organizational practices and processes intended to improve the natural environmental may be assessed at the organizational and environmental level, such as the economic impacts of pollution reduction (King and Lenox 2002) and the economic costs and environmental benefits of shared savings contracts for indirect materials (Corbett and DeCroix 2001). Regarding the role of information systems, the BAO framework may be applied to examine a variety of outcome types, such as the social and organizational phenomena that drive adoption of energy management systems (outcome as adoption), or the impact of energy management systems already in place (organizational structure) on $C0_2e$ and energy costs. Following is an overview of select issues concerning the outcomes of individual and organizational IS-enabled sustainability actions.

> **Research Question 7: What is the association between information systems and organizational and sustainability performance?**

IS and Organizational and Sustainable Performance: Production theory has been widely used in IS research to estimate the return on investment of IT (Black and Lynch 2001; Bresnahan et al. 2002) and the extent of substitutability between IT and other production inputs (Chwelos et al. 2009; Dewan and Min 1997). Useful metrics, such as the gross marginal return on investment, can be inferred from empirical studies employing production theory, as can the ease with which factors can be substituted for one another. In the case of sustainability research, production theory might be extended to examine new questions that extend the focus on organizational efficiency (Figure 2, link 4') to sustainability (Figure 2, link 5') (Cho et al. 2007). A dual-output production function (Kumbhaker 1987) might be employed to model the association between IT intensity, productivity, and greenhouse gas emissions by including both desired output (e.g., quantity of goods produced) and undesired output (CO_2e). Another approach would be to develop and estimate a structural model that examines predictors of energy intensity in production, including IT capital and regular capital, as done for the case of IT capital in the French service sector (Collard et al. 2005). Finally, given increased IT investment and questions about whether IT is associated with a net increase or decrease in energy use (Koomey 2007; Laitner 2003), production theory might be employed to examine the substitutability of IT equipment and energy (see Prywes 1986).

Research Question 8: What is the association between information systems and supply chain performance from an efficiency and environmental perspective?

IS and Supply Chain Environmental Performance: Transportation and logistics have been transformed by information and information technologies such as radio-frequency identification (RFID), enhancing the effectiveness of firms and growing new sources of revenue via information-based capabilities (Kohli and Melville 2009). From a sustainability perspective, IS enables firms to standardize, monitor, capture, and utilize data and metadata (e.g., location, temperature) that facilitates energy efficiencies. Overall, however, the role of IS may have dual effects. The first is to *increase* energy use by increasing energy inefficient transportation (air, truck) and nautical miles of shipping due to globalization and long distances between production and consumption (Romm 2002). The second is to *decrease* energy use by dematerialization (substituting digital goods such as ebooks for physical goods such as printed books), improving supply chain efficiency, and increasing capacity utilization. Estimates of the net impact of IS on freight transport quantity range from –17 percent to +31 percent (Erdmann et al. 2004) and of the reduction in business-as-usual year 2020 emissions by 1.52 Gt CO_2e from 51.9 Gt CO_2e (2.9 percent reduction) (Climate Group 2008).

Rigorous scholarly research is required to determine to what extent IS might improve sustainability in the realm of supply chains and logistics. Beyond energy, pollution is also an important phenomenon with respect to IS and supply chains. We do not know the extent to which rapid obsolescence of the physical equipment on which the digital age relies translates into waste containing toxic metals, nonrecyclable materials, and leaching plastics. Research is needed to examine and quantify this effect, including the efforts of equipment producers to produce greener equipment. One approach might be life cycle analysis, as discussed above, or case and field studies.

Research Question 9: How can firms optimally invest in industry IS platforms intended to reduce negative externalities associated with the natural environment?

Joint Investment in IS Platforms for Sustainability: A manufacturing supply chain typically involves several trading partners that collaborate to meet end-user demands (quality, timeliness, etc.). IS has been critical to supply chain activities by improving information flows and creating new sources of value (Banker et al. 2006; Cachon and Fisher 2000). Likewise, trading networks might proactively address sustainability by collaborating to promote environmental standards that they jointly develop. This regulation, in turn, may lead to joint investment in, for example, pollution reducing programs enabled by information systems. Analysis of issues arising in the context of joint investment in IS for sustainability might leverage the economics of IS literature on optimal investment in IS (Bakos and Nault 1997; Clemons and Kleindorfer 1992). Nault and Dexter (1995) show that aggregation of information can provide value-added services not possible otherwise. For example, joint investment in pollution remediation IS may not only achieve its stated purpose, but also enable data reuse for unanticipated benefits. This raises issues not only of optimal investment but also of allocation of value when trading partners collaborate in environmental information systems, similar to other types of value networks (Premkumar et al. 2004). Complicating matters is the perception of diminished power resulting from joint investment, which may act as a disincentive to invest in such systems (Clemons and Row 1993).

Research Question 10: How can systems approaches shed light on organizational and environmental outcomes that result from the use of IS for environmental sustainability?

Systems Approaches to IS and Environmental Performance: Reductionism is an approach to science that reduces problem complexity by assuming that the whole can be understood as the sum of its parts. In contrast, systems theory rejects reductionism by analyzing problems as a whole, which can yield new insights if the whole is more than the sum of its parts, as is often the case in the realm of sustainability (Bertalaffny 1969). Ackoff (1971) explicated the study of organizations as systems by defining a system as a set of interrelated elements with a set of relevant properties at a certain time (state), an environment containing elements outside the system that affect its state, and events which change the properties of the system. Information systems, by definition, are systems that are embedded in larger systems: "IS are systems that are included in business processes and these, in turn, are included in organizations, and the latter finally are included in their environment" (Mora et al. 2003,

p. 18). IS researchers have applied systems theory to examine such diverse problems as the impacts of information systems in organizations (Silver et al. 1995), the IS development process (Garrity 2002; Lewis 1994), and the dynamics of unwanted e-mail communication (Plice et al. 2007).

Thus systems theory has been viewed as foundational to the field of information systems (Alter 2001) and might be usefully applied to shed new light on sustainability outcomes from an organizational perspective. For example, feedback is inherent to complex systems. In the realm of sustainability, an example of feedback is the rebound effect, which occurs when energy conservation behavior is changed (use more) as a result of implementing more energy-efficient systems (which use less) (Herring and Sorrell 2008). Systems approaches might shed light on how IS may mediate or moderate the rebound effect by changing data and information availability. Another example is analyzing conservation regulation from a systems theory perspective. Use of system dynamics (Sterman 2001), which is a particular empirical formulation of systems theory, would enable modeling and analysis of the impact of adding new information signals at various points in the system on, for example, dematerialization (Hogg and Jackson 2008).

Review

In closing, we have put forth initial research questions exploring how information systems influence beliefs and affect actions concerning sustainability, as well as the association between IS and economic and environmental outcomes.The purpose was to illustrate a few of the many potential research issues that IS scholars might analyze. Other examples of IS research areas that might inform and be informed by environmental sustainability issues include (1) the role of the CIO in driving sustainability issues and influencing other business functions (Enns et al. 2003); (2) trust and privacy of individual and organizational resource data (Smith et al. 1996); and (3) the role of information systems agility in enabling expeditious changes to business processes congenial to environmental sustainability (Goodhue et al. 2009).

Conclusion

Environmental sustainability is one of the most important global challenges of the 21st century. According to renowned climate scientist James Hansen: "Our global climate is nearing tipping points. Changes are beginning to appear, and there is a potential for rapid changes with effects that would be irreversible—if we do not rapidly slow fossil fuel emissions during the next few decades."[13] The body of peer-reviewed climate science studies is unequivocal: anthropogenic climate change is a reality.[14] In the absence of expeditious action to decrease greenhouse gas emissions, the prognosis for many on planet earth due to lethal planetary overheating is grim.

By virtue of their dominance in the global economy, business organizations play a critical role in mitigating climate change and promoting environmental sustainability. Organizations pursue environmental sustainability by informing stakeholders of the need to make changes to business as usual, by motivating them to take actions to achieve environmental objectives, and by assessing the impact of such actions on economic and environmental performance.

Information systems are an important but inadequately understood weapon in the arsenal of organizations in their quest for environmental sustainability by enabling new practices and processes in support of belief formation, action formation, and outcome assessment. Research reports from Cisco (2008), McKinsey (Boccaletti et al. 2008), the Economist Intelligence Unit (EIU 2008), the Climate Group (2008), and the European Union (Barroso 2008) underscore the potential of IS to promote environmental sustainability. At the same time, popular media accounts paint IS as a villain, as illustrated by the following newspaper headlines: "Massive Computer Centers Bad for the Environment" and "American Electronic Waste Contaminates China and India."[15] IS scholarship is sorely needed to overturn half-truths, contribute to the body of knowledge about environmental sustainability, and develop a well-founded discourse on IS for environmental sustainability that leads to improvement of the natural environment.

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[13]See http://www.columbia.edu/~jeh1/mailings/2009/20090713_Strategies.pdf (accessed on 10/20/2009).

[14]A review of the scientific literature and the official positions of leading scientific organizations including the Intergovernmental Panel on Climate Change (IPCC), U.S. National Academy of Sciences, American Meteorological Society, and American Association for the Advancement of Science concludes that, "The question of what to do about climate change is also still open. But there is a scientific consensus on the reality of anthropogenic climate change. Climate scientists have repeatedly tried to make this clear. It is time for the rest of us to listen" (Oreskes 2004, p. 1686). The review analyzed 928 peer-reviewed studies of climate change listed in the *ISI* database published between the years 1993 and 2003: none disagreed with the consensus position of anthropogenic climate change.

[15]See, respectively, http://www.spiegel.de/international/business/0,1518,544053,00.html (accessed on 5/4/2009) and http://www.minesandcommunities.org/article.php?a=1809 (accessed on 5/4/2009).

In this paper, we offered a conceptual framework and a set of 10 research questions to expedite development and adoption of information systems for environmental sustainability and improve understanding of salient issues. Given the complexity of the topic, the first two research questions underscore the need for diverse knowledge-creation approaches (positivist, interpretive, critical, and design) and theories in studies of IS for environmental sustainability. Two research questions address research methodologies and metrics important to the sustainability domain but relatively new to IS scholarship, including life-cycle analysis, integrated assessment, and system dynamics modeling. The last set of six research questions addresses substantive issues in each of the three domains of the BAO framework for IS research on sustainability, such as how unique characteristics of the sustainability context (e.g., altruism) shape individual intention to use information systems for sustainability. Taken together, the BAO framework and research questions provide the basis for theory development in the realm of IS for sustainability.

The research questions are not intended to be definitive. The purpose is to illustrate how researchers might begin to tackle complex problems arising at the nexus of IS, organizations, and environmental sustainability. IS researchers have analyzed related problems in other contexts for decades, have developed a deep, relevant knowledge base, and are uniquely equipped to develop additional research questions and apply rigorous methods to their analysis and the analysis of research questions developed herein. At the same time, for certain research questions, collaboration across disciplines may accelerate knowledge development. For example, life cycle analysis may benefit from collaborations with operations management researchers.

Our tentative research agenda for information systems and environmental sustainability focuses on informing beliefs, enabling actions, and transforming outcomes. We urge IS scholars to conduct groundbreaking research that refines its perspectives, questions its premises, and puts flesh on its bones. Through this discourse, IS scholars can lead environmental sustainability into the digital age and thereby contribute to a healthy planet earth for generations to come.

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References

Abrahamse, W., Steg, L., Vlek, C., and Rothengatter, T. 2005. "A Review of Intervention Studies Aimed at Household Energy Conservation," *Journal of Environmental Psychology* (25), pp. 273-291.

Ackoff, R. 1971. "Towards a System of Systems Concepts," *Management Science* (17:11), pp. 661-671.

Ahlstrom, J., Macquet, M., and Richter, U. 2007. "The Lack of a Critical Perspective in Environmental Management Research: Distortion in the Scientific Discourse," *Business Strategy and the Environment* (18:5), pp. 334-346.

Alter, S. 2001. "Are the Fundamental Concepts of Information Systems Mostly about Work Systems?," *Communications of AIS* (5:11), pp. 1-67.

Bakos, J. Y., and Nault, B. R. 1997. "Ownership and Investment in Electronic Networks," *Information Systems Research* (8:4), pp. 321-341.

Banker, R., Bardhan, I., Chang, H., and Lin, S. 2006. "Plant Information Systems, Manufacturing Capabilities, and Plant Performance," *MIS Quarterly* (30:2), pp. 315-337.

Bansal, P., and Roth, K. 2000. "Why Companies Go Green: A Model of Ecological Responsiveness," *Academy of Management Journal* (43:4), pp. 717-736.

Barrieu, P., and Sinclair-Desgagne, B. 2006. "On Precautionary Policies," *Management Science* (52:8), pp. 1145-1154.

Barroso, J. M. D. 2008. "20 20 by 2020: Europe's Climate Change Opportunity," speech to the European Parliament, January 23, Brussels (available online at http://www.europa-eu-un.org/articles/en/article_7670_en.htm).

Bazerman, M., and Hoffman, A. 1999. "Sources of Environmentally Destructive Behavior: Individual, Organizational, and Institutional Perspectives," *Research in Organizational Behavior* (21), pp. 39-79.

Belk, R., Painter, J., and Semenik, R. 1981. "Preferred Solutions to the Energy Crisis as a Function of Causal Attributions," *Journal of Consumer Research* (8:3), pp. 306-312.

Berger, P., and Luckmann, T. J. 1966. *The Social Construction of Reality*, New York: Doubleday and Company, Inc.

Berkes, F., and Folke, C. 2000. "Linking Social and Ecological Systems for Resilience and Sustainability," in *Linking Social and Ecological Systems,* F. Berkes and C. Folke (eds.), Cambridge, England: Cambridge University Press.

Bertalaffny, L. 1969. *General System Theory: Foundations Development, Applications*, New York: George Braziller.

Black, S. E., and Lynch, L. M. 2001. "How To Compete: The Impact of Workplace Practices and Information Technology on Productivity," *The Review of Economics and Statistics* (83:3), pp. 434-445.

Blevis, E. 2007. "Sustainable Interaction Design: Invention & Disposal, Renewal & Reuse," in *Proceedings of the SICCHI Conference on Human Factors in Computing Systems*, San Jose, CA, April 28–May 3, pp. 503-512.

Boccaletti, G., Loffler, M., and Oppenheim, J. 2008. "How IT Can Cut Carbon Emissions," *McKinsey Quarterly*, October (available online at http://www.mckinsey.com/clientservice/ccsi/pdf/how_it_can_cut_carbon_missions.pdf).

Bock, G.-W., Zmud, R. W., Kim, Y.-G., and Lee, J.-N. 2005. "Behavioral Intention Formation in Knowledge Sharing: Examining the Roles of Extrinsic Motivators, Social-Pscychological Forces, and Organizational Climate," *MIS Quarterly* (29:1), pp. 87-111.

Bottrill, C. 2007. "Internet-Based Carbon Tools for Behavior Change," University of Oxford Environmental Change Institute, Oxford (available online at http://www.eci.ox.ac.uk/research/energy/downloads/botrill07-calculators.pdf).

Boudreau , M.-C., Chen , A., and Huber, M. 2007. "Green IS: Building Sustainable Business Practices," in: *Information Systems*, Global Text Project, 2007, pp. 1-15.

Bresnahan, T., Brynjolfsson, E., and Hitt, L. 2002. "Information Technology, Workplace Organization, and the Demand for Skilled Labor: A Firm-Level Evidence," *Quarterly Journal of Economics* (117), pp. 339-376.

Brown, T. 2008. "Design Thinking," *Harvard Business Review*, June, pp. 84-92.

Burgess, J., Harrison, C., and Filius, P. 1995. "Making the Abstract Real: A Cross-Cultural Study of Public Understanding of Global Environmental Change," unpublished study.

Cachon, G. P., and Fisher, M. 2000. "Supply Chain Inventory Management and the Value of Shared Information," *Management Science* (46:8), pp. 1032-1048.

Carberry, J. 2001. "Using Environmental Knowledge Systems at DuPont," in *Information Systems and the Environment,* D. J. Richards, B. R. Allenby, and D. Compton (eds.), Washington, DC: National Academy of Engineering, pp. 81-86.

Chen, C. 2001. "Design for the Environment: A Quality-Based Model for Green Product Development," *Management Science* (47:2), pp. 250-263.

Cho, Y., Lee, J., and Kim, T.-Y. 2007. "The Impact of ICT Investment and Energy Price on Industrial Electricity Demand: Dynamic Growth Model Approach," *Energy Policy* (35), pp. 4730-4738.

Chwelos, P., Ramirez, R., Kraemer, K., and Melville, N. 2009. "Does Technological Progress Alter the Nature of Information Technology as a Production Input? New Evidence and New Results," *Information Systems Research*, forthcoming.

Ciroth, A. 2007. "ICT for Environment in Life Cycle Applications: OpenLCA—A New Open Source Software for Life Cycle Assessment," *International Journal of Life Cycle Analysis* (12:4), pp. 209-210.

Cisco. 2008. "The Sustainability Business Practice Study," Cisco, San Jose, CA.

Clemons, E., and Kleindorfer, P. R. 1992. "An Economic Analysis of Interorganizational Information Technology," *Decision Support Systems* (8:5), pp. 431-446.

Clemons, E., and Row, M. 1993. "Limits to Interfirm Coordination through Information Technology: Results of a Field Study in Consumer Packaged Goods Distribution," *Journal of Management Information Systems* (10:1), pp. 73-95.

Climate Group. 2008. "SMART 2020: Enabling the Low Carbon Economy in the Information Age," The Climate Group (available online at http://www.gesi.org/LinkClick.aspx?fileticket=tbp5WRTHUoY%3d&tabid=60).

Coleman, J. S. 1994. *Foundations of Social Theory* (2nd ed.), Cambridge, MA: Harvard University Press.

Coleman, J. S. 1986. "Social Theory, Social Research, and a Theory of Action," *American Journal of Sociology* (91), pp. 1309-1335.

Collard, F., Feve, P., and Portier, F. 2005. "Electricity Consumption and ICT in the French Service Sector," *Energy Economics* (27:2), pp. 541-550.

Collins, C., Steg, L., and Koning, M. 2007. "Customers' Values, Beliefs on Sustainable Corporate Performance, and Buying Behavior," *Psychology and Marketing* (24:6), pp. 555-577.

Corbett, C. J., and DeCroix, G. A. 2001. "Shared-Savings Contracts for Indirect Materials in Supply Chains: Channel Profits and Environmental Impacts," *Management Science* (47:7), pp. 881-893.

Corbett, C. J., and Kirsch, D. A. 2001. "International Diffusion of ISO 14000 Certification," *Production and Operations Management* (10:3), pp. 327-342.

Daly, H. 1990. "Toward Some Operational Principles of Sustainable Development," *Ecological Economics* (2:1), pp. 1-6.

Davis, F. D. 1989. "Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology," *MIS Quarterly* (13:3), pp. 319-339.

Davis, F. D., Bagozzi, R. P., and Warshaw, P. R. "User Acceptance of Computer Technology: A Comparison of Two Theoretical Models," *Management Science* (35:8), pp. 982-1003.

Devaraj, S., Easley, R., and Crant, J. M. 2008. "How Does Personality Matter: Relating the Five-Factor Model to Technology Acceptance and Use," *Information System Research* (19:1), pp. 93-105.

Dewan, S., and Min, C. 1997. "The Substitution of Information Technology for Other Factors of Production: A Firm Level Analysis," *Management Science* (43:12), pp. 1660-1675.

Dumont, J., and Franjeska-Nicole, B.-C. 2008. "Learning About the Environment: The Role of Information Technology in Shaping Attitudes and Developing Solutions," SynEnergy Forum, University of Indianapolis, Indianapolis (available online at http://synenergy.teipir.gr/papers/VII_3.pdf).

EIU. 2008. "Managing the Company's Carbon Footprint: The Emerging Role of ICT," Unisys, The Economist Intelligence Unit Reports.

Elkington, J. 1994. "Towards the Sustainable Corporation: Win-Win-Win Business Strategies for Sustainable Development," *California Management Review* (36:2), pp. 90-100.

Enns, H., Huff, S. L., and Higgins, C. 2003. "CIO Lateral Influence Behaviors: Gaining Peers' Commitment to Strategic Information Systems," *MIS Quarterly* (27:1), pp. 155-174.

EPA. 2006. "Environmental Management Systems Benchmark Report," Environmental Protection Agency, Washington, D.C.

Erdmann, L., Lorenz, H., Goodman, J., and Arnfalk, P. 2004. "The Future Impact of ICTs on Environmental Sustainability," European Commission Joint Research Centre. (available online at ftp://ftp.jrc.es/pub/EURdoc/eur21384en.pdf).

Farrell, D., and Oppenheim, J. 2008. "The Carbon Productivity Challenge: Curbing Climate Change and Sustaining Economic Growth," McKinsey Global Institute (available online at http://www.fypower.org/pdf/MGI_Carbon_Productivity.pdf).

Fava, J. A. 1994. *A Technical Framework for Life-Cycle Assessment*, Pensacola, FL: SETAC Foundation.

Felin, T., and Foss, N. 2005. "Strategic Organization: A Field in Search of Micro-Foundations," *Strategic Organization* (3:4), pp. 441-455.

Felin, T., and Foss, N. 2006. "Individuals and Organizations: Thoughts on a Micro-foundations Project for Strategic Management and Organizational Analysis," in *Research Methodology in Strategy and Management,* D. J. Ketchen and D. D. Bergh (eds.), Amsterdam: Elsevier Ltd., pp. 253-288.

Fishbein, M., and Azjen, I. 1975. *Belief, Attitude, Intention, and Behavior: An Introduction to Theory and Research*, Reading, MA: Addison-Wesley Publishing.

Froehlich, J., Dillahunt, T., Klasnja, P., Mankoff, J., Consolvo, S., Harrison, B., and Landay, J. 2009. "UbiGreen: Investigating A Mobile Tool for Tracking and Supporting Green Transportation Habits," in *Proceedings of the 27th International Conference on Human Factors in Computing Systems*, Boston, MA, April 4–9, pp. 1043-1052.

Garrity, E. 2002. "Synthesizing User Centered and Designer Centered IS Development Approaches Using General Systems Theory," *IS Frontiers* (3:1), pp. 107-121.

Gephart, R. 1999. "Paradigms and Research Methods," *Academy of Management Research Methods Forum* (4), pp. 1-12.

Gladwin, T. N. 1993. "The Meaning of Greening: A Plea for Organizational Theory," in *Environmental Strategies for Industry: International Perspectives on Research Needs and Policy Implications,* K. Fischer and J. Schot (eds.), Washington, DC: Island Press, pp. 37-61.

Goodhue, D. L., Chen, D. Q., Boudreau , M. C., Davis, A., and Cochran, J. 2009. "Addressing Business Agility Challenges with Enterprise Systems," *MIS Quarterly Executive* (8:2), pp. 73-87.

Gregor, S., and Jones, D. 2007. "The Anatomy of a Design Theory," *Journal of the Association for Information Systems* (8:5), pp. 1-25.

Hammerstrom, D. J. 2007. "Pacific Northwest GridWiseTM Testbed Demonstration Projects," prepared for U.S. Department of Energy by the Pacific Northwest National Laboratory, Richland, WA (available online at http://gridwise.pnl.gov/docs/op_project_final_report_pnnl17167.pdf)

Hedstrom, P. 2005. *Dissecting the Social*, New York: Cambridge University Press.

Hedstrom, P., and Swedberg, R. 1998. *Social Mechanisms: An Analytical Approach to Social Theory*, New York: Cambridge University Press.

Heiskanen, E. 2000. "Managers' Interpretations of LCA: Enlightenment and Responsibility or Confusion and Denial," *Business Strategy and the Environment* (9), pp. 239-254.

Heng, M. S. H., and de Moor, A. 2003. "From Habermas's Communicative Theory to Practice on the Internet," *Information Systems Journal* (13), pp. 331-352.

Herring, H., and Sorrell, S. (eds.). 2008. *Energy Efficiency and Sustainable Consumption*. Basingstoke, England: Palgrave Macmillan.

Hevner, A., March, S., and Park, J. 2004. "Design Science in Information Systems Research," *MIS Quarterly* (28:1), pp. 75-105.

Hirschheim, R., and Klein, K. 1994. "Realizing Emancipatory Principles in Information Systems Development: The Case for ETHICS," *MIS Quarterly* (18:1), pp. 83-109.

Hoffman, A. 2006. "Getting Ahead of the Curve: Corporate Strategies that Address Climate Change," Pew Center on Global Climate Change (available online at http://www.pewclimate.org/docUploads/PEW_CorpStrategies.pdf)

Hogg, N., and Jackson, T. 2008. "Digital Media and Dematerialization: An Exploration of the Potential for Reduced Material Intensity in Music Delivery," *Journal of Industrial Ecology* (13:1), pp. 127-146.

Holmes, T. 2006. "Environmental Awareness Through Eco-Visualization: Combining Art and Technology to Promote Sustainability," in *Proceedings of the CHI2006 Workshop, About Face: Interface, Creative Engagement in the New Media Arts*, Montreal, Canada, April 22-23.

King, A. A. , and Lenox, M.,J. 2001. "Lean and Green? An Empirical Examination of the Relationship between Lean Production and Environmental Performance," *Production and Operations Management* (10:3), pp. 244-256.

King, A. A., and Lenox, M. J. 2002. "Exploring the Locus of Profitable Pollution Reduction," *Management Science* (48:2), pp. 289-299.

Klassen, R. D., and Vachon, S. 2003. "Collaboration and Evaluation in the Supply Chain: The Impact on Plant-Level Environmental Investment," *Production and Operations Management* (12:3), pp. 336-352.

Klein, H. K., and Myers, M. D. 1999. "A Set of Principles for Conducting and Evaluating Interpretive Field Studies in Information Systems," *MIS Quarterly* (23:1), pp. 67-94.

Kleindorfer, P. R., Singhal, K., and Wassenhove, L. N. V. 2005. "Sustainable Operations Management," *Production and Operations Management* (14:4), pp. 482-492.

Kohli, R., and Melville, N. P. 2009. "Learning to Build an IT Innovation Platform," *Communications of the ACM* (52:8), pp. 122-126.

Kolk, A. 2004. "A Decade of Sustainability Reporting: Developments and Significance," *International Journal of Environment and Sustainable Development* (3:1), pp. 51-64.

Koomey, J. 2007. "Estimating Total Power Consumption by Servers in the U.S. and the World,"Embargoed Review Draft, Lawrence Berkeley National Laboratory, Palo Alto, CA, February 15.

Kumbhaker, S. 1987. "The Specification of Technical and Allocative Inefficiency of Multi-product Firms in Stochastic Production and Profit Frontiers," *Journal of Quantitative Economics* (3), pp. 213-223.

Laitner, J. A. 2003. "Information Technology and U.S. Energy Consumption: Energy Hog, Productivity Tool, or Both?," *Journal of Industrial Ecology* (6:2), pp. 13-24.

Lee, Y., Lee, Z., and Gosain, S. 2004. "The Evolving Intellectual Diversity of the IS Discipline: Evidence from Referent Theoretical Frameworks," *Communications of AIS* (13), pp. 546-579.

Lewis, P. J. 1994. *Information Systems Development: Systems Thinking in the Field of Information Systems*, London: Pitman.

Lim, S., Malladi, S., Saldanha, T., and Melville, N. 2009. "Theories Used in Information Systems Research: Identifying Theory Networks in Leading IS Journals," in *Proceedings of the 30th International Conference on Information Systems*, Phoenix, AZ, December 15-18.

Linton, J. D., Klassen, R., and Jayaraman, V. 2007. "Sustainable Supply Chains: An Introduction," *Journal of Operations Management* (25:6), pp. 1075-1082.

Lopez, J., and Scott, J. 2000. *Social Structure*, Buckingham, England: Open University Press.

Lyon, T., and Maxwell, J. 2007. "Environmental Public Voluntary Programs Reconsidered," *Policy Studies Journal* (35:4), pp. 723-750.

March, T. S., and Smith, G. 1995. "Design and Natural Science Research on Information Technology," *Decision Support Systems* (15:4), pp. 251-266.

Markus, M. L., and Robey, D. 1988. "Information Technology and Organizational Change: Causal Structure in Theory and Research," *Management Science* (34:5), pp. 583-598.

Massey, A. P., Montoya-Weiss, M. M., and O'Driscoll, T .M. 2002. "Knowledge Management in Pursuit of Performance: Insights from Nortel Networks," *MIS Quarterly* (26:3), pp. 269-289.

Matos, S., and Hall, J. 2007. "Integrating Sustainable Development in the Supply Chain: The Case of Life Cycle Assessment in Oil and Gas and Agricultural Biotechnology," *Journal of Operations Management* (25:6), pp. 1083-1102.

Mazhar, M. I., Kara, S., and Kaebernick, H. 2005. "Remaining Life Estimation of Used Components in Consumer Products: Life Cycle Data Analysis by Weibull and Artificial Neural Networks," *Journal of Operations Management* (25:6), pp. 1184-1193.

Minbaeva, D. B., Makela, K., and Rabbiosi, L. 2007. "Absorptive Capacity and Knowledge Transfer: Individual Level," unpublished paper, Copenhagen Business School, 2007 (available online through http://cbs.dk).

Mingers, J. 2001. "Combining IS Research Methods: Towards a Pluralistic Methodology," *Information Systems Research* (12:3), pp. 240-259.

Mintzberg, H. 1979. *The Structuring of Organizations*, Englewood Cliffs, NJ: Prentice-Hall.

Montabon, F., Sroufe, R. P., and Narasimhan, R. 2007. "An Examination of Corporate Reporting, Environmental Management Practices and Firm Performance," *Journal of Operations Management* (25), pp. 998-1014.

Mora, M., Gelman, O., Cervantes, F., Mejia, M., and Weitzenfeld, A. 2003. "A Systemic Approach for the Formalization of the Information Systems Concept: Why Information Systems are Systems?," in *Critical Reflections on Information Systems: A Systemic Approach,* J. J. Cano (ed.), Hershey, PA: Idea Group Publishing, Hershey, pp. 1-29.

Morgan, M. G., and Dowlatabadi, H. 1996. "Learning from Integrated Assessment of Climate Change," *Climatic Change* (34:3-4), pp. 337-368.

Murray, J. 2007. "Why IT is Cleaning Up Its Act," *IT Week (UK)*, September 10.

Nault, B. R., and Dexter, A. S. 1995. "Added Value and Pricing with Information Technology," *MIS Quarterly* (19:4), pp. 449-464.

Ngwenyama, O., and Lee, A. 1997. "Communication Richness in Electronic Mail: Critical Social Theory and the Contextuality of Meaning," *MIS Quarterly* (21:2), pp. 145-167.

Noori, H., and Chen, C. 2003. "Applying Scenario-Driven Strategy to Integrate Environmental Management and Product Design," *Production and Operations Management* (12:3), pp. 353-368.

Nordhaus, W. D. 1993. "'Rolling the DICE': An Optimal Transition Path for Controlling Greenhouse Gases," *Resource and Energy Economics* (15:1), pp. 27-50.

Oreskes, N. 2004. "The Scientific Consensus on Climate Change," *Science* (306:5702), p. 1686.

Orlikowski, W., and Baroudi, J. J. 1991. "Studying Information Technology in Organizations: Research Approaches and Assumptions," *Information Systems Research* (2:1), pp. 1-28.

Pedersen, E. R., and Neergaard, P. 2006. "Caveat Emptor—Let the Buyer Beware! Environmental Labeling and the Limitations of 'Green' Consumerism," *Business Strategy and the Environment* (15), pp. 15-29.

Peffers, K., Tuunanen, T., Rothenberger, M., and Chatterjee, S. 2007. "A Design Science Research Methodology for Information Systems Research," *Journal of Management Information Systems* (24:3), pp. 45-77.

Pereira, A. G., and O'Connor, M. 1999. "Information and Communication Technology and the Popular Appropriation of Sustainability Problems," *International Journal of Sustainable Development* (2:3), pp. 411-424.

Plice, R., Pavlov, O., and Melville, N. 2007. "Spam and Beyond: An Information-Economic Analysis of Unwanted Commercial Messages," *Journal of Organizational Computing and Electronic Commerce* (18:4), pp. 278-306.

Porter, M., and Kramer, M. 2006. "Strategy and Society: The Link Between Competitive Advantage and Corporate Responsibility," *Harvard Business Review* (84:12), pp. 78-92.

Premkumar, G., Richardson, V., and Zmud, R. 2004. "Sustaining Competitive Advantage Through a Value Net: The Case of Enterprise Rent-A-Car," *MIS Quarterly Executive* (3:4), pp. 189-199.

Prywes, M. 1986. "A Nested CES Approach to Capital-Energy Substitution," *Energy Economics* (8:1), pp. 22-28.

Quak, H. J., and Koster, M. B. M. 2007. "Exploring Retailers' Sensitivity to Local Sustainability Policies," *Journal of Operations Management* (25:6), pp. 1103-1122.

Reinhardt, F., Mandelli, M., and Burns, J. 1999. "Environmental Risk Management at Chevron Corp.," Case Study #9-799-062, Harvard Business School.

Richards, D. J., Allenby, B. R., and Compton, D. (eds.). 2001. *Information Systems and the Environment*, Washington, DC: National Academy Press.

Robey, D. 2003. "Identity, Legitimacy and the Dominant Research Paradigm: An Alternative Prescription for the IS Discipline," *Journal of the Association for Information Systems* (4:7), pp. 352-359.

Romm, J. 2002. "The Internet and the New Energy Economy," *Resources, Conservation, and Recycling* (36:3), pp. 197-210.

Rose, S. 2008. "Staying Green in a Tough Economic Climate," *Harvard Business Review: HBRGreen.org* (available online at http://hbrgreen.org/2008/03/the_hard_economics_of_green.html).

Rothenberg, S., Pil, F. K., and Maxwell, J. 2001. "Lean, Green, and the Quest for Superior Environmental Performance," *Production and Operations Management* (10:3), pp. 228-243.

Schlumpf, C., Pahl-Wostl, C., Schonborn, A., Jaeger, C., and Imboden, D. 2001. "An Information Tool for Citizens to Assess Impacts of Climate Change from a Regional Perspective," *Climatic Change* (51), pp. 199-241.

Seligman, C., and Darley, J. M. 1977. "Feedback as a Means of Decreasing Residential Energy Consumption," *Journal of Applied Psychology* (62:4), pp. 363-368.

Sen, T. K., Moore, L. J., and Hess, T. J. 2000. "An Organizational Decision Support System for Managing the DOE Hazardous Waste Ceanup Program," *Decision Support Systems* (29:1), pp. 89-109.

Shaft, T. M., Ellington, R. T., Meo, M., and Sharfman, M. P. 1997. "A Framework for Information Systems in Life-Cycle-Oriented Environmental Management," *Journal of Industrial Ecology* (1:2), pp. 135-148.

Shaft, T. M., Sharfman, M. P., and Swahn, M. 2002. "Using Interorganizational Information Systems to Support Environmental Management Efforts at ASG," *Journal of Industrial Ecology* (5:4), pp. 95-115.

Sharma, R., and Yetton, P. 2009. "Estimating the Effect of Common Method Variance: The Method-Method Pair Technique with an Illustration from TAM Research," *MIS Quarterly* (33:3), pp. 473-490.

Shaw, D., and Clarke, I. 1999. "Belief Formation in Ethical Consumer Groups: An Exploratory Study," *Marketing Intelligence & Planning* (17:2), pp. 109-120.

Shrivastava, P. 1994. "CASTRATED Environment: GREENING Organization Studies," *Organization Studies* (15:5), pp. 705-726.

Sidorova, A., Evangelopoulos, N., Valacich, J., and Ramakrishnan, T. 2008. "Uncovering the Intellectual Core of the Information Systems Discipline," *MIS Quarterly* (32:3), pp. 467-482.

Silver, M., Markus, M. L., and Beath, C. 1995. "The Information Technology Interaction Model: A Foundation for the MBA Core Course," *MIS Quarterly* (19:3), pp. 361-390.

Smith, H. J., Milberg, S., and Burke, S. 1996. "Information Privacy: Measuring Inviduals Concerns about Organizational Practices," *MIS Quarterly* (20:2), pp. 167-196.

Sterman, J. D. 2001. "System Dynamics Modeling: Tools for Learning in a Complex World," *California Management Review* (43:4), pp. 8-28.

Straub, D., and Ang, S. 2008. "Readability and the Relevance Versus Rigor Debate," *MIS Quarterly* (32:4), pp. iii-xiii.

Straub, D., Gefen, D., and Boudreau, M.-C. 2005. "Quantitative Research," in *Research in Information Systems: A Handbook for Research Supervisors and Their Students,* D. Avison and Pries-Heje (eds.), Amsterdam: Elsevier, pp. 221-238.

Subramanian, R., Gupta, S., and Talbot, B. 2007. "Compliance Strategies Under Permits for Emissions," *Production and Operations Management* (16:6), pp. 763-779.

Tol, R. S. J. 2006. "Integrated Assessment Modelling," Working Paper FNU-102, Research Unit Sustainability and Global Change, Hamburg University, Hamburg.

Tschirhart, J. 2003. "Ecological Transfers Replace Economic Markets in a General Equilibrium Ecosystem Model," *Journal of Bioeconomics* (5), pp. 193-214.

Udehn, L. 2001. *Methodological Individualism: Background, History and Meaning*, London: Routledge.

van der Heijden, H. 2004. "User Acceptance of Hedonic Information Systems," *MIS Quarterly* (28:4), pp. 695-704.

Van Maanen, J. 1988. *Tales of the Field: On Writing Ethnography*, Chicago: University of Chicago Press.

Vastag, G. 2004. "Revisiting ISO 14000 Diffusion: A New "Look" at the Drivers of Certification," *Production and Operations Management* (13:3), pp. 260-267.

WCED (World Commission on Environment and Development). 1987. *Our Common Future*, Oxford, UK: Oxford University Press.

Welford, R. 1998. "Editorial: Corporate Environmental Management, Technology, and Sustainable Development: Postmodern Perspectives and the Need for a Critical Research Agenda," *Business Strategy and the Environment* (7:1), pp. 1-12.

Wixom, B. H., and Todd, P. A. 2005. "A Theoretical Integration of User Satisfaction and Technology Acceptance," *Information Systems Research* (16:1), pp. 85-102.

Zhang, P., Carey, J., Te'eni, D., and Tremaine, M. 2005. "Integrating Human-Computer Interaction Development into the Systems Development Life Cycle: A Methodology," *Communications of AIS* (15), pp. 512-543.

Zhu, Q., and Sarkis, J. 2004. "Relationships Between Operational Practices and Performance Among Early ADopers of Green Supply Chain Management Practices in Chinese Manufacturing Enterprises," *Journal of Operations Management* (22), pp. 265-289.

About the Author

Nigel P. Melville is an assistant professor of Business Information Technology at the Stephen M. Ross School of Business, University of Michigan. His research examines the mechanisms and consequences of IS innovation and has appeared in leading academic and professional journals such as *Information Systems Research*, *MIS Quarterly*, *Decision Support Systems*, and *Communications of the ACM*. He is an editor of the book *Global E-Commerce: Impacts of National Environment and Policy*. Professor Melville earned a B.S. in electrical engineering from the University of California, Los Angeles, an M.S. in electrical and computer engineering from the University of California, Santa Barbara, and a Ph.D. in management from the University of California, Irvine.

Appendix A

List of Identified Articles

Author	Title	Journal	Year	Topic
Angell, L. C.	Comparing the Environmental and Quality Initiatives of Baldrige Award Winners	POM	2001	ATO
Chinander, K. R.	Aligning Accountability and Awareness for Environmental Performance in Operations	POM	2001	ATO
Corbett, C.; Kirsch, D.A.	International Diffusion of ISO 14000 Certification	POM	2001	ATO
Corbett, C.	Global Diffusion of ISO 9000 Certification Through Supply Chains	MSOM	2006	ATO
Delmas, M.	Stakeholders and Competitive Advantage: The Case of ISO 14001	POM	2001	ATO
Klassen, R.D.	Plant-level Environmental Management Orientation: The Influence of Management Views and Plant Characteristics	POM	2001	ATO
Melnyk, S. A.; Sroufe, R. P.; Calantone, R. J.	A Model of Site-specific Antecedents of ISO 14001 Certification	POM	2003	ATO
Vastag, G.	Revisiting ISO 14000 Diffusion: A New “Look” at the Drivers of Certification	POM	2004	ATO
Caro, F.R.; Andalaft, P.; Sapunar, M.; Cabello, M.	Evaluating the Economic Cost of Environmental Measures in Plantation Harvesting Through the Use of Mathematical Models.	POM	2003	PERF
Corbett, C.; DeCroix, G.A.	Shared-savings Contracts for Indirect Materials in Supply Chains: Channel Profits and Environmental Impacts	MS	2001	PERF
Dowell, G.; Hart, S.; Yeung, B.	Do Corporate Global Environmental Standards Create or Destroy Market Value?	MS	2000	PERF
Kassinis,G.I.; Soteriou, A.C.	Greening the Service Profit Chain: The Impact of Environmental Management Practices	POM	2003	PERF
King, A.; Lenox,M.	Lean and Green? An Empirical Examination of the Relationship Between Lean Production and Environmental Performance	POM	2001	PERF
King, A.; Lenox,M.	Exploring the Locus of Profitable Pollution Reduction	MS	2002	PERF
Levi, M. D.; Nault, B. R.	Converting Technology to Mitigate Environmental Damage	MS	2004	PERF
Melnyk, S. A.; Sroufe, R.P.; Calantone, R.	Assessing the Impact of Environmental Management Systems on Corporate and Environmental Performance	JOM	2003	PERF
Montabon, F.; Sroufe, R; Narasimhan, R.	An Examination of Corporate Reporting, Environmental Management Practices and Firm Performance	JOM	2007	PERF
Pil, F. K.; Rothenberg, S.	Environmental Performance as a Driver of Superior Quality	POM	2003	PERF
Sroufe, R.	Effects of Environmental Management Systems on Environmental Management Practices and Operations	POM	2003	PERF
Woensel, T. V.; Creten, R. C.; Vandaele, N.	Managing the Environmental Externalities of Traffic Logistics: The Issue of Emissions	POM	2001	PERF
Zhu, Q.; Sarkis, J.	Relationships Between Operational Practices and Performance among Early Adopters of Green Supply Chain Management Practices in Chinese Manufacturing Enterprises	JOM	2004	PERF

Author	Title	Journal	Year	Topic
Bowen, F. E.; Cousins, P. D.; Lamming, R.C.; Faruk, A. C.	The Role of Supply Management Capabilities in Green Supply	POM	2001	SC
Klassen, R.D.; Vachon, S.	Collaboration and Evaluation in the Supply Chain: The Impact on Plant-level Environmental Investment	POM	2003	SC
Kocabasoglu, C.; Prahinski, C.; Klassen, R. D.	Linking Forward and Reverse Supply Chain Investments: The Role of Business Uncertainty	JOM	2007	SC
Matos, S.; Hall, J.	Integrating Sustainable Development in the Supply Chain: The Case of Life Cycle Assessment in Oil and Gas and Agricultural Biotechnology	JOM	2007	SC
Mazhar, M. I.; Kara, S.; Kaebernick, H.	Remaining Life Estimation of Used Components in Consumer Products: Life Cycle Data Analysis by Weibull and Artificial Neural Networks	JOM	2007	SC
Quak,H. J.; de Koster, M. B. M.	Exploring Retailers' Sensitivity to Local Sustainability Policies	JOM	2007	SC
Chen, C.	Design for the Environment: A Quality-Based Model for Green Product Development	MS	2001	PD
Noori, H.; Chen, C.	Applying Scenario-Driven Strategy to Integrate Environmental Management and Product Design	POM	2003	PD
Rothenberg, S.; Pil, F. K.; Maxwell, J.	Lean, Green, and the Quest for Superior Environmental Performance	POM	2001	LEAN
Barrieu, P.; Sinclair-Desgagne, B.	On Precautionary Policies	MS	2006	POL
Subramanian, R.; Gupta, S.; Talbot, B.	Compliance Strategies under Permits for Emissions	POM	2007	POL
Heng, M.S.H.; de Moor, A.	From Habermas's Communicative Theory to Practice on the Internet	ISJ	2003	IS
Kleindorfer, P.R.; Singhal, K.; Van W.;Luk N.	Sustainable Operations Management	POM	2005	REV
Linton, J. D.; Klassen, R.; Jayaraman, V.	Sustainable Supply Chains: An Introduction	JOM	2007	REV

Note: European Journal of Information Systems (EJIS), Information Systems Journal (ISJ), Journal of Operations Management (JOM), Management Science (MS), Manufacturing and Service Operations Management (MSOM), Production and Operations Management (POM). Time period: 2000-2007. **ATO**: antecedents to adoption of environmentally sustainable practices; **PERF**: performance outcomes of environmentally sustainable practices; **SC**: supply chains and environmental sustainability; **PD**: product design for environmental sustainability; **LEAN**: lean manufacturing and environmental sustainability; **POL**: public policy issues; **IS**: information systems for environmental sustainability; **REV**: review of the literature.