TOWARDS A REFERENCE MODEL FOR ECOLOGICAL IT SERVICE MANAGEMENT

Completed Research Paper

Markus Reiter
Institute for Information Systems (IWi) at the German Research Center for Artificial Intelligence (DFKI) and Saarland University
Campus, Building D 3 2
66123 Saarbruecken, Germany
markus.reiter@iwi.dfki.de

Peter Fettke
Institute for Information Systems (IWi) at the German Research Center for Artificial Intelligence (DFKI) and Saarland University
Campus, Building D 3 2
66123 Saarbruecken, Germany
peter.fettke@iwi.dfki.de

Peter Loos
Institute for Information Systems (IWi) at the German Research Center for Artificial Intelligence (DFKI) and Saarland University
Campus, Building D 3 2
66123 Saarbruecken, Germany
peter.loos@iwi.dfki.de

Abstract

The incorporation of ecological objectives in the design of information systems has gained increasing attention by IS research in recent years. Nevertheless, from the perspective of IT Service Management (ITSM), comprehensive approaches are still warranting attention. The objective of this paper is therefore to develop a process for the management of ecology in ITSM. By using the method of reference modeling, the widely-used IT Infrastructure Library (ITIL) is extended by a new process category, called Ecology Management. Based on a requirements analysis, four ecology management processes are introduced: Resource Substitution Management, Resource Efficiency Management, Resource Demand Management, and Ecological Transparency Management. In addition, interrelations to the existing ITIL processes are built by defining ecological concepts, like Green Incidents, or Green SLAs. These results are validated for the example of Green Incident Management in the related consortium research project. An important limitation is the focus on ITSM.

Keywords: IT Service Management, Ecology, Reference Modeling

Motivation

Ecology has become one of the major topics for IS research in recent years. In Watson et al. (2012) it is even argued, that "the current customer service dominant logic is being replaced or complemented by a sustainability dominant logic, which reflects the growing concern with environmental issues". In conjunction with this observed development, the research for Green Information Technology (Green IT), and Green Information Systems (Green IS) have considerably evolved (Loos et al. 2011). Research covers, among others, the design of energy-efficient hardware, innovative concepts for cooling and energy supply of data centers, virtualization and consolidation of servers, success factors for the implementation of Green IS in organizations, or the effects of feedback on the energy consumption behavior of consumers (Brooks et al. 2010). Besides that, the incorporation of ecological objectives in governance frameworks for IT service provision and information systems management has established as another area of interest (Butler 2011; Schmidt et al. 2009a).

The governance of IT service provision is usually covered by IT Service Management (ITSM) frameworks, like the IT Infrastructure Library (ITIL), or the Control Objectives for Information and related Technology (CoBiT). ITSM frameworks are originated in practice. They support the customer-centric dominant logic by aiming at transforming technology-driven IT organizations into customer- and process-oriented organizations. The main objective of ITSM is the definition, implementation, operation, and improvement of IT services, which serve at executing the business processes of a customer organization. Therefore, customer-oriented concepts have been introduced, covering e.g. the definition of Service Level Agreements (SLAs) between customer and IT organization, the establishment of escalation procedures, if the provision of these services is threatened (incident management), or by increasing transparency about service qualities through reporting customer-oriented performance indicators. Popular examples for IT services are social networks, internet-based business applications, online storage, internet search, or social funding. IT services, in turn, require physical IT resources for their operation. These are, among others, servers, disc systems, network equipment, data center buildings, or cooling. The provision and operation of these IT resources in time and quality is another central objective for IT Service Management.

Concerning the importance of IT service provision for economy and society on one hand, and the increasing concerns about sustaining planet's ecosphere on the other, there is the emerging need for ecological extensions concerning IT service provision. Currently, there have been first discussions about the option to incorporate ecological objectives in ITSM frameworks (Dubey and Hefley 2011), but related work still seems to be in its early stages. The objective of this paper is therefore to develop an ecology management process which shall be integrated with existing ITSM processes. The research method used to develop that process is reference modeling. Reference modeling is an established design-oriented research approach, serving, among others, for the provision of domain knowledge, which is independent from individual solutions. In order to achieve a potentially high acceptance rate, the reference model will be developed as extension of the established IT Infrastructure Library (Office of Government Commerce 2010). The intended construction process of the reference model is visualized in Figure 1.

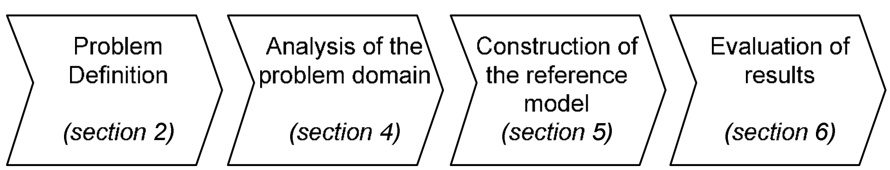

Figure 1. Procedure of Reference Modeling, derived from Fettke and Loos (2004)

The paper is structured as follows: After this introduction, the state-of-the-art of IT Service Management and Green IS will be presented in section 2. Section 3 introduces the method of reference modeling. In section 4, an analysis of the problem domain will be accomplished to derive the requirements for ecology management in ITSM. After that, the Ecology Management Process will be introduced and presented in section 5. In addition, necessary interrelations with existing ITSM processes will be discussed on the example of Incident Management. After that, an evaluation plan and the results achieved so far will be provided in section 6. Finally, a discussion of the results and an outlook on future work will be presented.

State-of-the-Art and Problem Definition

The awareness for ecological objectives in Information Systems Research (ISR) has increased in the last years. The preservation of the natural environment can be derived from the concept of sustainability, which aims at the preservation of the current level of welfare, the conservation of the environment and equal chances for all people (World Commission on Environment and Development 1987). For ISR, the evolution of *Green IT* can be regarded as an outcome of this general development, as it aims at decreasing the environmental impact of Information Technology. Originated in practice, the concept of Green IT can be defined as *"the study and practice of designing, manufacturing, using, and disposing of computers, servers, and associated subsystems – such as monitors, printers, storage devices, and networking and communications systems – efficiently and effectively with minimal or no impact on the environment"* (Murugesan 2008). This definition can clearly be associated with the idea of reducing the environmental footprint of IT *(Green for IT)*. Nevertheless, the more promising approach to use IT as leverage for greening other disciplines, such as manufacturing, is intensely discussed and reflected by the terms *IT for Green*, or *Green IS* (Watson et al. 2010). Examples for current areas of interest in the research on Green IS and Green IT are, among others, factors which contribute to successful adoption of Green IS (Chen et al. 2009), or the relationship between Green IS measures and the economic and ecological performance of a company (Nishant et al. 2012). Furthermore, ecological management instruments like a sustainability balanced scorecard or green capability maturity models are proposed for further investigation (Schmidt et al. 2009a). In the smart metering context, the interdependencies between the transparencies in energy usage and user behavior are of particular interest. Findings show, that user behavior can be directed towards lower energy consumption, if the behavior of social reference groups is made transparent to each individual (Loock et al. 2012). In addition, Green IS can be realized through outsourcing scenarios, if excess demand is provided via cloud solutions, leading to a reduction in the need for installed IT resources (Dorsch and Häckel 2012). For data centers, popular measures for the reduction of energy consumption cover, among others, the virtualization and consolidation of servers, as well as adapted cooling concepts, the use of renewable energy, or the use of energy efficient hardware (Howard and Holmes 2012).

Green IS measures can be derived from general ecological objectives, which have been developed in several theoretical contributions. By establishing a framework of energy informatics, Watson et al. (2010) refer to the ecological goals of *eco efficiency, eco effectiveness,* and *eco equity*. These ecological objectives incorporate efficiency increases (eco efficiency), the design of sustainable products and services (eco effectiveness) and the fair access to resources for all people (eco equity). Another popular theoretical foundation is provided in Hart (1995) by introducing the natural-resource-based view of the firm. In this work, the overall ecological objectives of *pollution prevention, product stewardship,* and *sustainable development* are introduced. Pollution prevention addresses the reduction of pollution of the natural eco system and shall be achieved through the increase of efficiency in industrial production processes. It is therefore close to eco efficiency. Product stewardship addresses the design of sustainable products and can be aligned whit eco effectiveness. Sustainable development, in turn, can easily be attributed to eco equity and the overall concept of sustainability.

Besides the provision of a theoretical foundation for individual Green IS measures, there is also an awareness that IS Governance needs to be adapted to support Green IT and Green IS initiatives. In this context, Schmidt et al. (2009b) provide the concept of a sustainable information management, which is based on the resource-based view of the firm. In Erek et al. (2009) a framework for structuring different Green IT measures is provided. This framework is based on the value chain of information management, including the categories *source, make, deliver, return,* and *organizational issues*. Another example for a Green IS framework is proposed in Butler (2011), who separated Green IS strategy into *people, energy efficiency, dematerialization, waste and recycling,* as well as *green operations*.

IT Service Management is originated in practice and has not been used as governance framework for Green IS so far. It can be regarded as a sub-category of IT Governance and aims at the customer-oriented and process-oriented provision of IT services (Hochstein et al. 2005). ITSM covers the governance of IT service provision, as it defines processes and guidelines for the proper management of incidents, changes, user requests, or reporting. During its evolution, ITSM has extended its scope, so further processes, like system acquisition, strategy development, or continuous improvement processes have been included in popular ITSM frameworks, although not all functions are covered by all frameworks. Popular examples for ITSM frameworks are the IT Infrastructure Library or the Control Objectives for Information and Related Technology.

ITIL is the most popular ITSM framework and is applied by a large number of professional IT companies (Galup et al. 2009). Initially developed by the British Central Computing and Telecommunications Agency (CCTA), it is available in its 3rd revision since 2007, and is now maintained by the Office of Government Commerce, OGC (Office of Government Commerce 2010). ITIL provides descriptions on how to manage IT service production from a lifecycle-oriented perspective, including the major categories Service Strategy, Service Design, Service Transition Service Operation, and Continual Service Improvement. These categories are further separated into 26 single ITSM processes, like Service Level Management, Capacity Management, Change Management, Service Reporting, or Continuous Service Improvement (Figure 2).

1) Service Strategy	2) Service Design	3) Service Transition	4) Service Operation	5) Continual Service Improvement
1a) Strategy Generation	2a) Service Catalogue Management	3a) Transition Planning and Support	4a) Event Management	5a) 7-Step Improvement Process
1b) Financial Management	2b) Service Level Management	3b) Change Management	4b) Incident Management	5b) Service Reporting
1c) Service Portfolio Management	2c) Capacity Management	3c) Service Asset and Configuration Management	4c) Request Fulfillment	
1d) Demand Management	2d) Availability Management	3d) Release and Deployment Management	4d) Problem Management	
1e) Organizational Development	2e) IT Service Continuity Management	3e) Service Validation and Testing	4e) Access Management	
	2f) Information Security Management	3f) Evaluation		
	2g) Supplier Management	3g) Knowledge Management		

Figure 2. Overview of ITIL V3, derived from Office of Government Commerce (2010)

ITIL has evolved as a comprehensive framework for IT Service Management. Its strengths are its popularity and acceptance in practice. Furthermore, ITIL can serve as a frame of reference for ITSM, which is a necessary element in reference modeling. Most of the processes are interconnected. For example, Incident Management, which is important for the quick resolution of events which may affect system availability and performance, passes each incident to Problem Management. Problem Management in turn, aims at identifying the potential underlying problems, which serves at preventing future incidents. After solutions have been found, they are implemented using Change Management and Release Management. Service Level Management defines the thresholds for each IT service, which need to be guaranteed towards the customer and which may not be violated. Depending on these agreements, events are regarded as incidents (if they affect service level), or can be handled with less importance.

ITIL has already been identified as a suitable leverage for the incorporation of ecological objectives into IT organizations (Dubey and Hefley 2011). In Reiter et al. (2012) a qualitative analysis of all ITIL processes has been conducted in order to identify their potentials for the incorporation of ecological extensions. The most promising processes in this analysis were Capacity Management, Availability Management, IT Service Continuity Management, Problem Management, Service Reporting, Event Management, Service Level Management, and Incident Management. Another ecological extension to ITSM is proposed in Schmidt et al. (2009a) by the incorporation of a sustainability balanced scorecard and by the ecologically extended concept of the capability maturity model.

Nevertheless, Green IS research has upon now not made significant use of ITSM for incorporating ecological objectives into IT organizations. As ITSM frameworks are accepted in practice and provide well-designed instruments for managing IT service provision, they should be extended for managing ecology.

Research Method: Reference Modeling

The discipline of reference modeling has evolved in the German-speaking community of *Wirtschaftsinformatik* (Fettke 2009). Reference modeling has different scientific roots which can be traced back to the 1930ies (Thomas 2005). A popular example for an established reference model is the Y-CIM reference model for industrial enterprises, which includes data models and process descriptions for the manufacturing industry (Scheer 1998). A comprehensive overview of early work on reference modeling in Germany can be found in Fettke and Loos (2004). Although originated in German-speaking countries, the discipline has received increasing attention in international research on information systems, information modeling and conceptual modeling (Thomas 2005). Clearly, reference models can be classified as conceptual models (Frank 2007). As conceptual models aim at building a formal representation of a modeling domain (Wand and Weber 2002), this is also true for reference models.

The characterizing attributes of reference models are their reusability, their universal applicability and their recommendation character, which implies their applicability as standards and best practices (Fettke and Loos 2004). The main intentions behind the creation of reference models are to speed up individual modeling processes (Noran 2006), and to capture, save and transfer economic knowledge (Fettke and Loos 2004). Reference models provide domain-specific architectures (Becker and Schütte 2007). The common characteristics of individual solutions in such domains are condensed through abstraction and serve as generic patterns for reuse. Reference models need to be derived from a sufficient number of individual observations, so that they can be regarded as ideal solution or at least, as “best practice” in the respective domain. Alternatively, reference models can be created by complementing existing reference models with additional elements, which satisfy new or adapted requirements (Otto and Ofner 2010). In summary, reference models can briefly be characterized as accessible, formal or semi-formal normative or descriptive conceptual representations of a domain, which demonstrated their reusability.

Currently, the discipline of reference modeling has established itself internationally and has received increased attention in the last years. Related work covers for example the development of reference models for Manufacturing Execution Systems (Schmidt et al. 2011), Energy Management (Schlieter et al. 2010), or Supply Chain Management (Otto and Ofner 2010). Current and international accepted examples for reference models are the Supply Chain Operations Reference Model (SCOR), the enhanced Telecom Operations Map (eTOM), American Productivity & Quality Center’s Process Classification Framework (PCF), or the IT Infrastructure Library (ITIL). ITIL includes world-wide accepted procedures for the provision of IT services, which are derived from practice, and which are documented using natural and semi-formal language. ITIL is applicable to all kinds of IT organizations and provides best practices. Therefore, it fulfills the requirements of user acceptance, as well as the attributes of universality and recommendation character. As a consequence, it can clearly be classified as a reference model.

Reference models are IT artifacts in the sense of design science research (vom Brocke and Buddendick 2006). Accepted design principles for reference models have been identified as instantiation, aggregation, specialization, and analogy construction (vom Brocke 2007). Concerning the creation process of reference models, suitable approaches have for example been proposed in Fettke and Loos (2004) or Ahlemann and Gastl (2007). These procedures differ between the number of steps and the individual actions which need to be conducted in order to create a reference model. Nevertheless, all procedures include a kind of problem definition or requirements specification, which is usually followed by the creation and the evaluation of the respective reference model. Alternatively, generic and widely accepted processes for developing design science artifacts, like introduced in Peffers et al. (2007), can be applied to develop and evaluate reference models.

The design process which will be used in this work has consequently been condensed from the actual state-of -the-art, and has already been provided in Figure 1. It has mainly been derived from Fettke and Loos (2004), and Ahlemann and Gastl (2007). It covers first the problem definition, which serves for identifying the objective of the reference model (step 1). Then, an analysis of the problem domain is performed to capture the relevant domain knowledge and to derive the corresponding requirements (step 2). Thereafter, the initial version of the reference model is constructed, using established instruments for reference modeling (step 3), as are e.g. conceptual data models, business process models, or functional diagrams (Ahlemann and Gastl 2007). Finally, the evaluation of the reference model is foreseen as step 4.

Analysis of the Problem Domain

Hierarchy of Ecological Objectives

The incorporation of ecological objectives in IS can directly be derived from the concept of sustainability. Sustainability is usually observed from three perspectives: An economic perspective, a social perspective and an ecological perspective. As the focus of this paper is ecology, the social perspective and the economic perspective will be out of scope. The ecological perspective covers, in general terms, the preservation of nature. This means that the exploitation of natural resources may not exceed their regeneration rates, and that emission rates may not exceed the assimilative capacities of the natural ecosystem (Daly 1990). Natural resources can be distinguished between renewable resources and non-renewable resources (Ruth 2002). Renewable resources shall be defined as natural resources which recover at least at the same speed at which they are consumed. Non-renewable resources, in turn, are natural resources, which do not recover, or which recover at a speed which makes them unavailable for a very long time horizon. In consequence, to realize ecological objectives in IS, the primary objective needs to be the substitution of non-renewable resources by renewable resources (Andre and Cerda 2005; Tahvonen and Salo 2001), and will be named Ecological Objective I. As long as this cannot be achieved, it must be the secondary ecological objective to use as little of non-renewable resources as possible. Most effective for that is the reduction of the overall quantities which are exploited (Ecological Objective II). Usually, the increase of energy efficiency, or more commonly, the increase of resource efficiency are proposed as solutions to support this objective (Bartelmus 2003; Ehrenfeld 2005). Porter and van der Linde (1995) pledge for increasing resource efficiency as means to achieve an alignment between both ecological and economic objectives. So, increasing resource efficiency will consequently be defined as Ecological Objective IIa. Nevertheless, as long as the demand for products and services surmounts the gains in efficiency increase, the continuing exploitation of non-renewable resources cannot be prevented (Dahlstrom and Ekins 2005). Therefore, resource efficiency gains need to be complemented by demand control (Ecological Objective IIb). Figure 3 summarizes the derived hierarchy of ecological objectives.

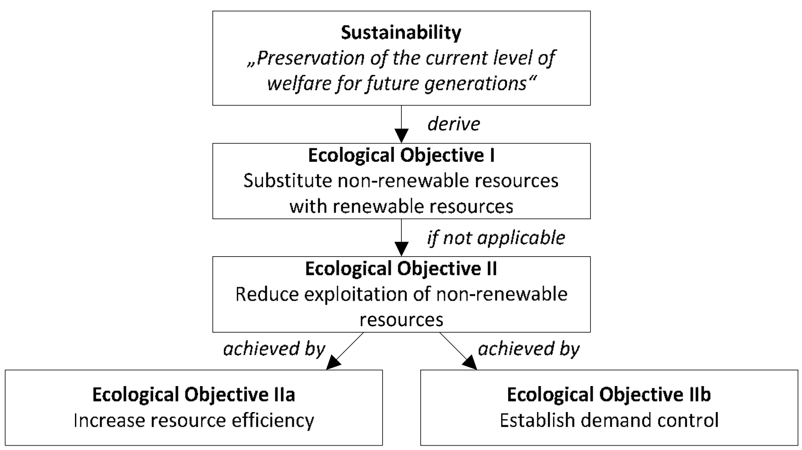

Figure 3. Hierarchy of Ecological Objectives

Actual Support of Ecological Objectives in IT Service Management

Prior to the deduction of ecological requirements from the developed goal hierarchy, the actual support of these ecological objectives in ITSM will be analyzed, using the example of ITIL. To support that, the perspectives "Green for ITSM" and "ITSM for Green" are introduced in analogy to "Green for IT" and "IT for Green". "Green for ITSM" covers all actions which support ecological objectives during the execution of individual ITSM processes. In contrast to that, the perspective "ITSM for Green" covers all extensions to ITSM which support ecological objectives in the business processes of a customer organization.

Perspective "ITSM for Green". ITIL was designed to transform IT organizations from pure technology-oriented entities to customer-, process- and service-oriented organizations. Therefore, ITIL covers procedures which have been found useful for the management of an IT organization. Customer-centric thinking is e.g. reflected by the introduction of a service catalogue, and the necessity to agree upon service qualities (SLA's). These service qualities cover business-related objectives, like performance objectives, reaction times, service times, or availability objectives. Ecological objectives have not been foreseen, although the given structures could be extended to consider them as well. ITIL's processes like Event Management, Incident Management, or Problem Management are dedicated to monitor thresholds, which are business-related (like availabilities of services), and to start resolution procedures, if these business objectives are threatened. Service Reporting and Continual Service Improvement serve at informing the customer of the IT organization about the performance of the IT service provider, focusing on an achievement of business objectives. The Continual Service Improvement process must be classified as business-related, too. Nevertheless, Service Reporting can be extended to consider ecological indicators, like emissions, or the share of renewable energy sources. Availability Management or Service Continuity Management are dedicated to the proper operation of the IT service and have actually been designed to support the availability of IT services. The hierarchy of ecological objectives as it has been defined in the previous section is not covered by these processes. Resource substitution is not a design constraint of ITIL. Resource efficiency is only covered from an economic perspective, but not explicitly mentioned. Although there are some mechanisms to adjust provided capacities to customer demand (Demand Management, Capacity Management), a process to reduce customer demand actively is not provided.

Perspective "Green for ITSM". From the perspective "Green for ITSM" the consideration of ecological objectives is analyzed for the execution of the ITSM processes themselves. Event Management, Incident Management, or Service Reporting are assessed in terms of their consideration of ecological objectives, e.g. being efficient in the use of resources, or using a high share of renewable resources for their operation. Given Ecological Objective I, ITSM processes need to make use of a large share of renewable resources. Furthermore, resource efficiency must be supported, which can be assessed by the use of energy efficient hardware, the amount of material required (e.g. use of paper), and the amount of emissions produced. For Ecological Objective IIb, the overall number of instances of executed ITSM processes needs to be reduced. Actually, ITIL does not foresee any mechanisms to reduce the number of process executions. For the processes themselves, the objectives substitution (I), or resource efficiency (IIa) are not covered. This finding fits into ITIL's design constraint, which is related to customer-orientation and service-orientation. For the perspective "Green for ITSM", ITIL's processes should be regarded as conventional business processes, which possess an individual resource consumption pattern and which can be optimized with green business processes reengineering methods. Currently, an ecologically oriented execution cannot be observed for ITIL's processes.

Requirements for an Ecologically Extended IT Service Management

The analysis in the previous section showed, that ITIL does not explicitly support any of the ecological objectives I-IIb. In the following section, the requirements for ecological extensions to ITSM will be derived, which is an essential step towards the construction of the reference model. The development will be done in an argumentative-deductive manner, and is based on the hierarchy of ecological objectives.

Requirement 1: Substitution of Non-Renewable Materials

In correspondence to Ecological Objective I, the first requirement for an ecological ITSM is to support the replacement of non-renewable resources by renewable resources (Daly 1990). This objective has been identified as an important environmental and economic issue in related research on ecology management and resource policies (Andre and Cerda 2005; Graedel 2002; Tahvonen and Salo 2001). For Information Systems, although IT services are immaterial, the provision of IT services relies on physical IT resources, as are hardware, buildings, and other equipment. IT resources need to be based on renewable resources, including renewable materials as well as renewable energy sources. Therefore, ITIL needs to implement functions which classify the used resources, and which enable the switching to other resources, when feasible. For example, the availability of regenerative energy sources should imply the use of this energy source. The measure becomes even more effective, if coupled with load balancing. The execution of IT services needs to be delayed until renewable energy sources (sun, wind) are available. For materials, the use of scarce materials must be avoided as much as possible. Instead of that, purchasing policies need to demand the procurement of IT resources, which are easy to recycle, energy efficient and built of environmentally friendly and renewable materials. An appropriate resource usage control systems needs to be put in place. This system needs to introduce a classification scheme of all used resources in IT service production and appropriate criteria like their natural recovery rate. Non-renewable resources must be identified by a monitoring system and substitute materials must be identified and be put in place. For those non-renewable resources which cannot be substituted, secondary ecological objectives, like resource efficiency and demand control need to be pursued.

Requirement 2: Increase of Resource Efficiency

Eco efficiency (Ehrenfeld 2005), resource efficiency, resource productivity, energy efficiency (Dahlstrom and Ekins 2005), or dematerialization (Bartelmus 2003) are commonly representing the concept of improving a given input-output-ratio, usually by decreasing the required input for a desired output. In this paper, the increase of resource efficiency has been classified as a secondary ecological objective. In case of IT service provision the outputs are the IT services, which need to satisfy the economically driven qualities, which have been agreed in the Service Level Agreements (as availability, maximum downtime, service time, or reaction time). As SLAs need to be fulfilled, resource efficiency in the context of IT service provision can only be achieved by reducing the inputs which are required for fixed outputs. Inputs for IT service provision are IT resources (hardware and infrastructure), energy, and human workforce. The material input can be reduced by extending the lifecycles of IT resources. Energy efficiency must be achieved by procuring energy efficient hardware. Furthermore, resource efficiency and energy efficiency need to be included in future Service Level Agreements and need to be monitored by Event Management. As ITIL supports the concept of interrelated processes, this concept must be implemented in Incident Management and Problem Management, too. In these processes, new concepts are required to create awareness for resource inefficiencies and trigger appropriate actions, if efficiency objectives are not met.

Requirement 3: Demand Management

Although resource efficiency has been identified as an essential element of the hierarchy of ecological objectives, it is not sufficient, as it may only lead to a relative decoupling of outputs and required inputs (Dahlstrom and Ekins 2005). For IT, as long as the production of IT services is facing an increasing demand, efficiency gains are therefore likely to be compensated. As a consequence, absolute decoupling is required, referring to the situation in which there is an overall reduction in required material inputs or pollution outputs, whether through productivity improvements, a decrease in outputs, or a combination of the two (Dahlstrom and Ekins 2005). A decrease in outputs can be realized through the principle of Demand Management (Ecological Objective IIb). Demand Management means the active management of required resources and is typically applied in water demand management (Kampragou et al. 2011), energy demand management (Dyer et al. 2008), or for managing the demand for transportation services (Smith 2008). For IT, it must be assured that the number of installed IT resources capacities do not over-compensate efficiency gains. As requirements to Demand Management, the following mechanisms need to be incorporated into ITIL. First, Demand Management needs to be active. Most effectively, this can be achieved by the agreement of progressive charging rates between the IT service provider and the customer (Özlük et al. 2010). As soon as the customer exceeds an agreed capacity of installed IT resources, the charging will be increased. This requires the installation of a transparent reporting, which delivers actual consumption data, preferably on real-time basis, and which needs to be coupled with the charging systems. In addition to progressive charging, load balancing needs to be implemented in ITIL. Based on customer agreements, IT service provision can be delayed, until sufficient IT resource capacities are available. Third, ITIL needs to incorporate appropriate purchasing policies, closely coupled with the capacity management process. Effective prediction mechanisms are essential for the procurement of IT resources which match future needs but are not over-estimated. This should include setting fixed thresholds for IT resource occupation, preventing any usage if the reserved capacities are exceeded (capping). In addition to that, it can be beneficial from an ecological point of view, to source excess capacities from a cloud provider (Dorsch and Häckel 2012).

Requirement 4: Ecological Transparency

Defining and applying environmental indicators is an important prerequisite for the goal-oriented management of ecology in organizations. In accordance with the European Environmental Agency (EEA), an environmental indicator provides information about phenomena that are regarded typical and/or critical to environmental quality (Smeets and Weterings 1999). Popular ecological and environmental indicators are among others, energy flow and material flow indicators, terrestrial indicators (carbon footprint, ecological footprint, or water footprint), indicators of life-cycle assessment, as well as indicators of environmental risk assessment (Herva et al. 2011). For Green IS research, ecologically motivated reporting mechanisms are e.g. proposed by the introduction of the sustainability balanced scorecard or green maturity models (Schmidt et al. 2009a). Furthermore, transparency has been found effective for changing energy consumption behavior, for example in smart home environments (Loock et al. 2011). For corporations, the idea of the Environmental Management Information Management System (EMIS) has a rather long tradition, providing environmental information (Teuteberg and Straßenburg 2009). In consequence, defining and reporting ecological key performance indicators is a prerequisite for the active ecological management of IT-organizations, serving to create awareness for ecological objectives, and for tracing their effectiveness. As a consequence, an essential requirement is the definition of key performance indicators, which reflect ecological objectives. These need to cover, among others, usage of renewable and non-renewable resources, energy efficiency, emissions of greenhouse gases, or occupied capacities. As a complement, the amount of provided IT services needs to be tracked, e.g. provided storage, provided user accounts, or the number of backups per period. The corresponding measurement and analyzing systems need to be put in place. For ITSM processes, this requires in particular the adaption of Event Management and Service Reporting.

Introduction of Ecology Management

Description of the Process Category

After the deduction of the requirements from the hierarchy of ecological objectives, suitable ecological extensions to ITSM will be proposed in this section. This is realized by introducing a new process category, Ecology Management (Figure 4).

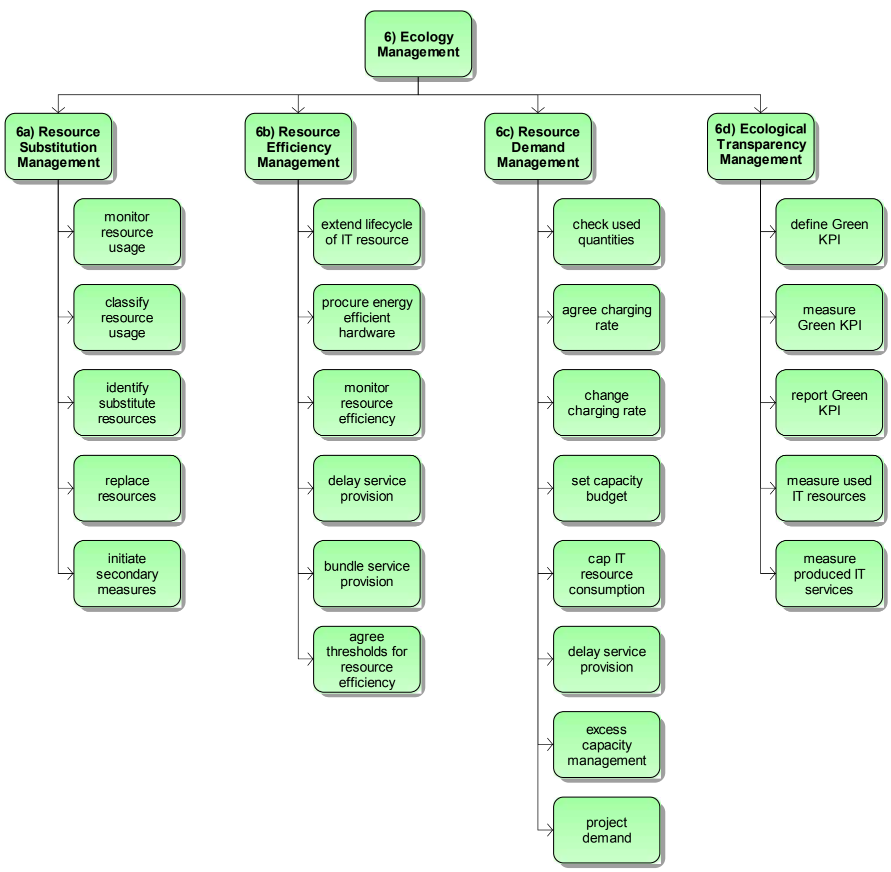

Figure 4. Functional Diagram of Ecology Management, Proposition as new Process Category to ITIL

The definition as an independent process group stresses the importance of the ecological objectives and sets a balance against the traditional, economically motivated ITSM processes. Ecology Management covers four sub processes, which correspond to the requirements, which were deducted in the previous section. These sub processes are Resource Substitution Management, Resource Efficiency Management, Resource Demand Management, and Ecological Transparency Management. Besides the new process category, interrelations to existing ITSM processes will be used as much as possible, in order to enable a smooth incorporation of the new concepts into existing structures.

Ecology Management is proposed as a complementing process group to ITIL's existing management framework. It is not part of the lifecycle, but it is covering a specific topic: the management of the ecological goal hierarchy in an IT organization. An important complement of Ecology Management will be its interrelation with the remaining ITIL processes. Therefore, conceptual extensions will be introduced to central concepts of ITIL, as are Service Level Agreements, KPIs, Events, Incidents, Changes, and Problems. Considering the ecological objectives, these central concepts of ITIL will be extended as follows:

- A Green Service Level Agreement (Green SLA) will be defined as an agreement between an IT organization and its customers, which includes both economic and ecological objectives. In Green SLAs the options for the IT organizations are agreed, concerning the applicability of the different functions of Ecology Management. For example, in Green SLAs, charging systems are agreed, as well as the allowance of service shifting, or the establishment of capacity budgets for the underlying IT resources. As customer commitment to ecology is crucial for the success of Ecology Management, the definition of Green SLAs is essential for all functions of Ecology Management.
- A Green Key Performance Indicator (Green KPI) will be defined as an element which aims at measuring the achievement of an ecological objective. A Green KPI is expressed as a number or ratio and is bound to a specific ecological objective, like the substitution of non-renewable resources, or the resource efficiency of non-renewable resources. Examples for Green KPIs are the percentage of substitute materials, the overall resource efficiency, or the total amount of emissions and waste.
- A Green Event will be defined as the detectable occurrence of any circumstances, which can be attributed to ecology. Green Events cover the usage of natural resources, the availability of regenerative energy, the occurrence of emissions, or the energy which is consumed by an IT resource. The detection of a Green Event is a necessary precondition for the calculation of Green KPIs and the detection of Green Incidents.
- A Green Incident is defined as a Green Event which threatens the agreements, which have been defined in Green SLAs. A Green Incident covers for example the unexpected usage of energy by a certain IT resource, or the unwanted use of seldom materials. In accordance to the general principle of an incident, Green Incidents define situations which require reaction at short notice. To avoid concurrence with conventional incidents, Green Incidents shall receive a lower priority than conventional incidents.
- A Green Problem represents the fundamental threat to the achievement of ecological objectives. As conventional problems, Green Problems can arise from Green Incident Management, representing e.g. the general resource inefficiency of an IT resource. Green Problem Management aims therefore at solving all problems, which prevent the achievement of ecological objectives.
- A Green Change aims at changing the configuration of IT resources in a way, which enables the better realization of ecological objectives. An example of a Green Change is the replacement of IT resources by IT resources with better resource efficiency.
- A Green Service Report aims at providing the performance of Green KPIs and the achievement of Green SLAs towards the customer. Green Service Reports are therefore a complement to traditional reports and support at integrating the idea of ecological objectives into another central conceptual element of customer-oriented IT Service Management.

The reasons for extending central concepts of ITIL by an ecological perspective is the creation of awareness for ecology in IT organizations, and the establishment of an interconnection to the newly introduced process group of Ecology Management. Whereas the traditional processes of ITIL provide the preconditions for the treatment of ecological issues in ITSM, the treatments themselves will be fulfilled by the sub processes of Ecology Management. This requires interfaces between the individual process group and a transfer of information, as well as close collaboration. So it can be assured, that ecological extensions are not implemented as single elements into an individual process. Instead, it is made use of ITIL's structure of interrelated processes, allowing the realization of network effects, and positive feedback loops. One example are the Green KPIs, which are monitored in Event Management, interpreted and solved in Green Incident Management, and which are passed for a general resolution to Resource Substitution Management, or Resource Demand Management. Besides the establishment of holistic control and management processes, this interrelationship of ITIL's processes is one central design constraint for the incorporation of ecological objectives into the framework.

Furthermore, as ITIL has been designed to implement customer-oriented IT organizations, customer-integration has been considered for the definition of the ecological extensions. The customer of IT service provision needs to support ecological objectives e.g. by asking for ecologically designed IT services, by agreeing to Green SLAs, or by accepting Green Incidents as a new class of incidents. The customer is essential for the realization of an ecological IT service provision. It seemed therefore appropriate to introduce new functions into ITIL, which support the customer-oriented design of services, as well as Green SLAs, Green KPIs, and Green Service Reporting. These extensions are implemented in the corresponding ITIL processes, which are, among others, Service Offering Portfolio, Service Level Management, Event Management, Incident Management, Problem Management, Change Management, Service Reporting, and Continual Service Improvement.

After ecological extensions have been introduced to established ITIL processes, the newly introduced sub processes of Ecology Management will be described in the following section.

Resource Substitution Management

Resource Substitution Management supports Ecological Objective I. Therefore, it aims at replacing non-renewable resources which are used for IT service provision by renewable resources. Therefore, the process consists of corresponding functions for the monitoring and classification of resource usage and for identifying non-renewable resources as well as appropriate substitutes. After substitutes have been identified, the process supports the replacement of non-renewable resources by renewable resources. One common example is the use of regenerative energy sources. As soon as regenerative energy is available, a switching to this energy sources needs to be initiated. If coupled with further mechanisms, like shifting service execution, the provision of IT services can be bound to the availability of regenerative energy. The most important Green KPIs are the usage percentage of renewable resources (in relation to total resources), and the number of substitutions, as well as the contribution of each substitution to the total share of renewable resources in IT service production. Close interrelations need to be established to ITIL's Supplier Management in order to initiate the selection or appropriate suppliers. Furthermore, the usage of non-renewable resources needs to be agreed with the customer in the Green SLAs. The defined Green KPIs will be monitored in Event Management, and will be escalated in Green Incident Management. (Green) Problem Management will serve for solving deficiencies in resource substitution, whereas Service Reporting is useful to report the actual achievements towards customers and further stakeholders.

Resource Efficiency Management

Resource Efficiency Management serves at decreasing the ratio of non-renewable resources which are required for the provision of a fixed amount of IT services. Therefore, it supports Ecological Objective IIa. The underlying assumption is that the used IT resources cannot be replaced by renewable resources. For that purpose, Resource Efficiency Management is designed to include functions which are bound to lifecycle management, or to the procurement of resource efficient hardware and infrastructure devices. Furthermore, the agreement of efficiency thresholds needs to be assured, which is typically done in the agreement of Green SLAs. Thresholds need to be monitored and appropriate actions need to be taken, if these thresholds are exceeded. For this purpose Event Management and Incident Management are useful. The concept of the Green Incident is effective for reacting at short notice to unforeseen resource inefficiencies during IT service provision. Innovative resolution methods can include the shifting of services (if the load of underlying IT resources is not optimal). Appropriate KPIs for Resource Efficiency Management are IT Service Efficiency, and IT Resource Efficiency, which should be incorporated into Event Management and Service Reporting.

Resource Demand Management

Resource Demand Management is the complementing factor to Resource Efficiency Management. Both processes serve at supporting Ecological Objective II, which is the reduction of the use of non-renewable resources in absolute numbers. In consequence, the demand must be managed in a way, that besides efficiency, demand for IT services is projected and reduced (Ecological Objective IIb). Therefore, the process of Resource Demand Management needs to provide functions for the projection of demand and the required IT resources. Furthermore, the use of IT resources needs to be monitored and reported. Appropriate action needs to be taken, if the agreed thresholds are in danger to be exceeded. For Resource Demand Management, the charging towards the customer needs to be adapted. This can be done as a penalty (if the customer exceeds an agreed capacity budget), or as an incentive (if the customer requires less resources than agreed). In addition, IT resource capacities can be managed using outsourcing scenarios. Peak capacities can be sourced via internet-based service provision, so that no local capacities need to be installed (Dorsch and Häckel 2012). If customers agree, even a capping of installed IT resources can be considered. For example, the number of storage occupied per user in an email system can be limited to a fixed threshold. Green KPIs for Resource Demand Management cover the IT resource budget per customer and user, the amount of IT resources, which are currently used, the charging rates agreed, or the projected demand of each customer. Resource Demand Management has close interrelations to Service Level Management (Green SLAs), Event and Incident Management, Service Reporting, and especially to Supplier Management and Capacity Management. Capacity Management is already intended to provide capacities in accordance with customer demand. Its design objectives will now be motivated by the ecological objectives, too.

Ecological Transparency Management

Awareness and transparency are implemented through Ecological Transparency Management as the fourth sub processes of Ecology Management. Awareness was created exemplarily in the previous sections, by introducing the concepts of the Green Incidents and Green SLAs. By doing so, awareness for the need of ecological extensions is created in one of the most important ITIL processes and in the central element of provider-customer-agreements. Furthermore, this awareness needs to be supported in each of ITIL's life cycle categories, starting from strategy and budgeting, Service Level Management (as already shown), Change Management, or Reporting. Closely coupled to awareness is transparency. Transparency has been identified as a major prerequisite for the change in user behavior concerning their energy usage, e.g. in Smart Metering Environments (Loock et al. 2012). Therefore, it seems appropriate to define an individual process for ecological transparency management. ITIL should incorporate this principle to report its stakeholders about the ecological KPIs, which have been introduced for all processes of Ecology Management, reliably and at short notice. This does not only cover information for IT management, but also reporting towards ecological compliance organizations and customers of the IT organization. The implemented functions cover the definition of Green KPIs, the measurement of Green KPIs, the reporting of Green KPIs, as well as the measurement of used IT resources and provided IT services.

After the process of Ecology Management has been provided in this section, the next sections will cover the adaption of one of the most important processes of ITIL, which is Incident Management. The concept of the Green Incident has already been introduced, so it is now the objective to describe the implications for that process in detail and to establish an interface to Ecology Management.

Ecological Extensions for Incident Management

The actions, which are related to Green Incidents, differ from conventional incidents. If a Green Incident is trigged by an event which exceeds an ecological threshold, a Green Incident resolution procedure is required. This resolution procedure needs to cover actions for increasing resource efficiency, or for managing demand. Therefore, Green Incident Management relies on functions which are provided by Resource Efficiency Management, and Resource Demand Management. The appropriate functions which fit to the concept of an incident are the delay of service provision, excess capacity management, the adaption of charging rates and the capping of resource consumption. In Figure 5, the proposition of a Green Incident Management Process is provided in EPC notation (van der Aalst et al. 2002). The process model is based on a commercial ITIL reference model (Software AG 2007), which is complemented by ecological extensions. The extensions cover, most importantly, interfaces towards other ITIL processes and to Ecology Management, which fulfills the function of resolving the Green Incidents.

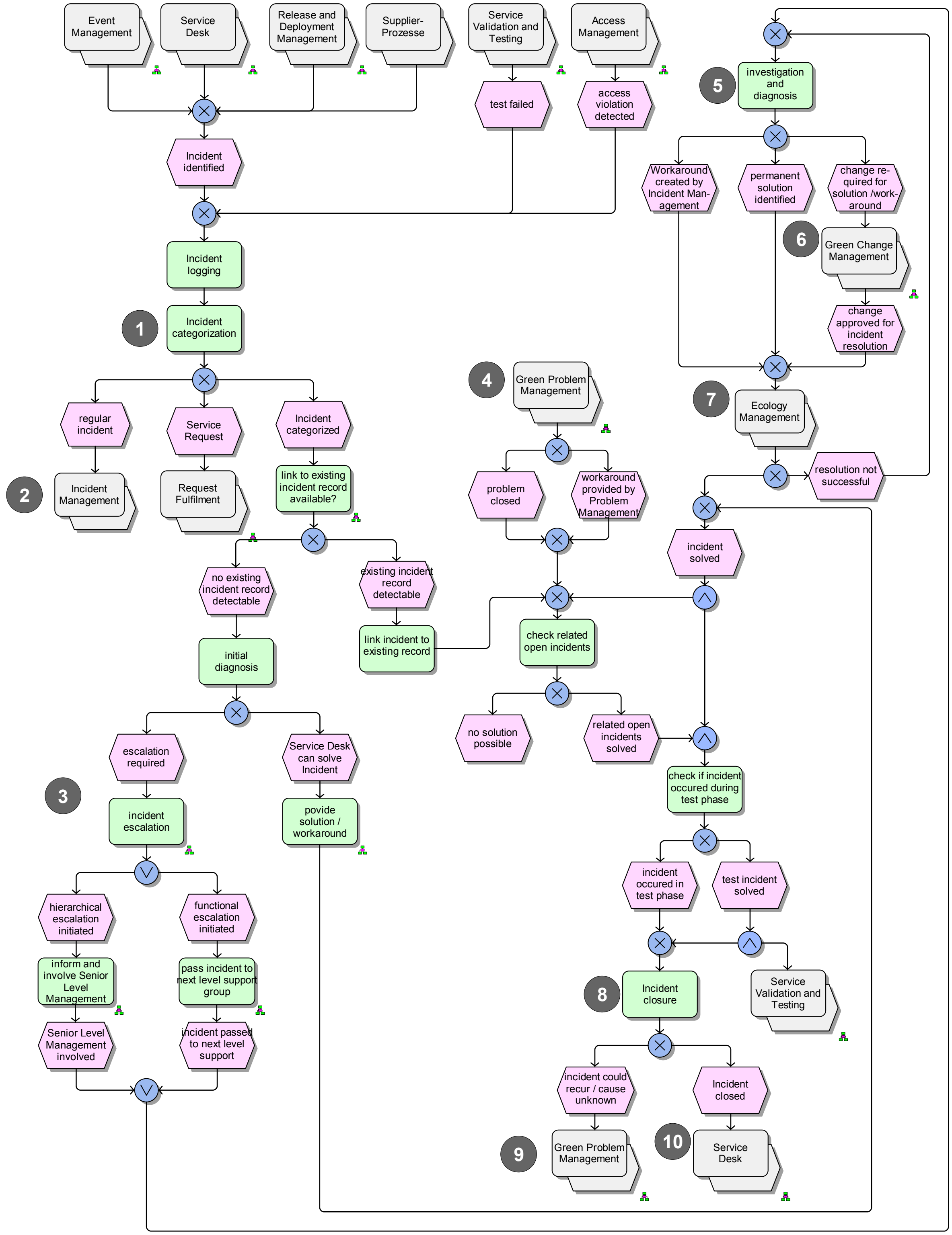

Figure 5. Coordinating Process for Green Incident Management, derived from the ITIL Reference Model Database for ARIS (Software AG 2007)

The central conceptual extension of the Green Incident supports the ecological objectives resource efficiency and demand management. It can be used to create awareness for resource inefficiencies and for unexpected capacity usages. Furthermore, the concept supports at creating ecological transparency. The priority of Green Incidents has been defined as less urgent as conventional incidents, which are usually related to unforeseen outages or performance problems of mission-critical IT services. Essential is the definition of a Green Incident as a relation between a Green Event and a Green SLA which incorporates ecologically extended quality elements. A Green SLA is valid for an individual customer and affects the IT services, which are provided to that customer. Besides Event Management and Service Level Management, it must be assured that Green Incidents are passed to Problem Management, so that an interface to Problem Management is defined.

In contrast to the regular incident process of ITIL, the following adaptions have been made to the process. First, incident categorization now differentiates between conventional incidents and green incidents (1). In case of conventional incidents, the regular incident management process is routed. Furthermore, the handling of major incidents has been eliminated for the Green Incident Management process, as Green Incidents are usually regarded with less priority than conventional incidents (2). An escalation of Green Incidents has nevertheless been foreseen, covering e.g. incidents which cause severe impact to the natural environment (3). An interface to Green Problem Management is foreseen (4), enabling the general handling of problems which affect ecological objectives. Investigation and diagnosis (5) is left unchanged with exception of Change Management, which is replaced by Green Change Management (6). Most important is the inclusion of Ecology Management (7), which is responsible of the resolution of a Green Incident. This covers the execution of the functions which have been introduced in Figure 4, and the routing towards the appropriate sub processes of Ecology Management. Incident closure (8) has been defined in analogy to conventional incident management. If the cause of the Green Incident is unknown, or if it is likely to recur, it is passed to Green Problem Management for handling (9). Otherwise, the incident is closed (10).

Evaluation of Results

Evaluation Plan

Evaluation serves at demonstrating the utility, quality, and efficacy of any design artifact, using well-executed evaluation methods (Hevner et al. 2004). It is one of the essential activities of creating any design artifact (March and Smith 1995). Evaluation can focus on the design object itself, or on the process of designing the artifact, it can be performed before and after implementing the artifact in its foreseen context, and it can be evaluated in natural or artificial settings (Pries-Heje et al. 2008). Accepted evaluation methods cover feature comparison, theoretical and conceptual investigation, meta modeling, metrics analysis, paradigmatic analysis, contingency identification, ontological investigation, and cognitive evaluation, as well as empirical evaluation techniques like surveys, laboratory experiments, field experiments, case studies, action research, or verbal protocols (Siau and Rossi 2011). The choice of the right evaluation instrument depends on the stage in the evaluation process, as well as on the evaluation objectives and the evaluation criteria. A comprehensive overview about suitable variables for planning and conducting the evaluation of design science artifacts can be found in Cleven et al. (2009).

The evaluation of reference models, as special design artifacts, is challenging and can be conducted from different perspectives, covering an economic perspective, a deployment perspective, an engineering perspective, and an epistemological perspective (Frank 2007). This approach is followed in some related work on designing specific reference models, like Otto and Ofner (2010) or Schmidt et al. (2011). The economic perspective evaluates the quantifiable costs and benefits of the reference model. The deployment perspective stresses the ability and willingness of the users to deal with the reference model, covering understandability and attitude to the model. The engineering perspective aims at testing the model against the requirements and the intended purpose of the model, whereas the epistemological perspective evaluates the preciseness of the descriptions, the right application of generic principles, like originality and abstraction, or the scientific progress which has been achieved (Frank 2007).

In this work, the evaluation object is the ecologically extended reference model for IT Service Management, namely Ecology Management and the conceptual extensions to the traditional ITSM processes. As the reference model of ecological IT service management has been deducted from the requirements which are based on the hierarchy of ecological objectives (Figure 3), it makes sense to evaluate the model from an engineering perspective, meaning that the fulfillment of the ecological requirements will be assessed. In this case, suitable evaluation criteria are "share of non-substitutable resources which was replaced by substitutable resources" (objective I), "increase in resource efficiency" (objective IIa), as well as "reduction of overall amount of consumed resources" (objective IIb). Suitable metrics are the substituted mass of non-renewable resources in the production process (objective I), the ratio of resources required for the production of one unit of a product or service (objective IIa), and the total amount of consumed resources (objective IIb). In case of raw materials, a suitable quantitative measure is the required mass (in kg). Energy can be traced back to raw materials, too. Nevertheless, a direct measurement of energy seems more comprehensive, so the required energy will be measured directly (in kWh). As a complement to energy and resource consumption, the emissions in the production process will be registered, using the established measure of carbon dioxide footprint (in kg).

The evaluation process will be split into different phases and will be executed in iterations, in accordance with state-of-the-art-procedures (Peffers et al. 2007). The primary design objective, the support of ecological objectives by using IT Service Management, will be evaluated from different perspectives. First, the concept will be presented to target organizations. Iteration one is dedicated at receiving qualitative feedback about the evaluation object. By conducting case studies, first in-depth results from applying the proposed reference model shall be collected. Appropriate target organizations are IT service providers as well as ITSM consulting companies. As soon as experts agree to the ecological extensions, a field test is foreseen in iteration two. It covers the implementation of the conceptual extensions, like Green SLAs and the processes of Ecology Management, into a real organization. The field test serves at assessing the effects of ecology management in a real business environment, including the feedback of customers, management and technical experts. In addition, the measurement of the resources consumed will be conducted, using the criteria and metrics, which have been defined above (Figure 6).

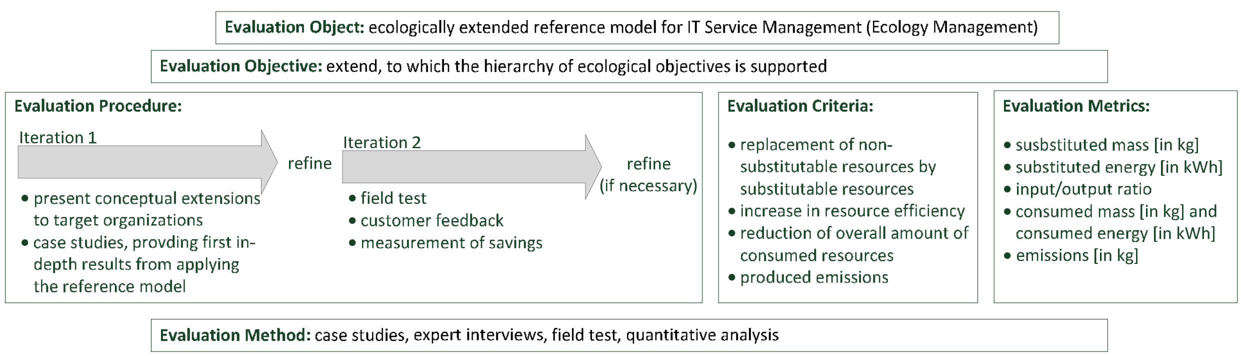

Figure 6. Evaluation Plan for Ecology Management

First Results

A pre-validation has been accomplished with industry partners in the related consortium research project. As a representative for the ecological extensions, the concept of the Green Incident was selected and related statements were compiled and were submitted to process experts with ITIL certification. Thus, experts were supposed to judge the general eligibility of the Green Incident concept on the basis of statements like *"Incident Management can be used to treat the violation of ecological thresholds in customer processes"*.

The pre-validation was done for the perspectives "ITSM for Green" and "Green for ITSM". Furthermore, the questions were designed to satisfy different perspectives on the Green Incident Concept, like its general acceptability by customers and IT organizations, possible design criteria for Green Incidents, as well as its interrelations to other concepts of ITSM. The experts, which were asked to reply to the statements, had the choice among three options for their answers ("agree", "partly agree", "disagree"). In total, 19 different statements have been phrased and were passed to the ITIL experts. The aggregated results are provided in Table 1.

Table 1. Statements for Evaluating the Potentials of the Green Incident Concept (Iteration 1)

Statement	Result
Perspective "Green for ITSM"	
Incidents shall not only be triggered, when performance or availability (of IT services) are threatened, but also when ecological limits are exceeded ("Green Incidents").	agree
The process of Incident Management can be used to treat the violation of ecological limit values in customer business processes.	partly agree
The provision of IT services can be delayed, if this has been agreed in the Service Level Agreements.	agree
Customer demand can be managed using adaptive charging rates and tariffs.	agree
The process of Incident Management can be interpreted as a management process, which can be used to treat the violations of any limit values.	agree
The green incident concept contributes to an improved awareness of ecological objectives in IT organizations.	agree
The green incident concept contributes to an improved awareness of ecological objectives in customer organizations.	partly agree
Green Incidents should have a lower priority than conventional incidents.	agree
Green Incidents should be triggered when non-renewable energy sources are used.	disagree
Green Incidents should be triggered, when the total amount of used resources is too high.	partly agree
Green Incidents should be treated in an independent Green Incident Management Process.	partly agree
Green Incidents require the prior agreement of Green Service Level Agreements.	partly agree
Green Incidents should be triggered, when IT resources are not optimally occupied.	agree
Customer demand can be managed through reporting mechanisms.	disagree
Perspective "ITSM for Green"	
Travelling in Incident Management can be reduced by pooling with other activities.	partly agree
A close collaboration with the logistician reduces transport efforts in Incident Management.	partly agree
The green incident concept contributes to an improved awareness of ecological objectives in IT organizations.	agree
Incident Management consumes most of its resources during problem solving.	partly agree
The IT infrastructure which is necessary for the execution of an Incident Management Process can be operated using renewable energy sources.	disagree
Incident Management can be used to treat the violation of ecological limit values in other ITSM processes.	partly agree

Discussion

This work aimed at providing a solution to the problem of incorporating ecological objectives into IT organizations. The approach followed was to use well-established ITSM frameworks, like ITIL, as leverage. The concepts, which are provided by ITSM, like Incident or Service Level Agreement, have been found suitable and easily adaptable to new objectives, so ITSM benefits from its own architecture. A necessary precondition was the deduction of appropriate ecological objectives. This was achieved by deriving the hierarchy of ecological objectives from the overall concepts of sustainability and ecology. This analysis could be supported by related literature to ecology and provides four areas of action, namely the substitution of non-renewable resources, the increase of resource efficiency, the establishment of demand control and the introduction of ecological transparency. These areas have consequently been used to derive requirements and to define the new process category of Ecology Management in a traceable and comprehensible fashion.

In the pre-validation, the concept of the Green Incident was evaluated exemplarily. The experts, which were asked to evaluate the ecological extensions, assigned an equally high significance to the Green Incident concept in comparison to conventional incidents, which cover only availability problems and performance problems. In the same way Green Incidents can raise the awareness for ecological goals in IT and customer organizations. However, in comparison experts see less effectiveness of the concept for customer organizations, which, nevertheless, is still sufficient. Green Incidents shall mainly be triggered in case of high resource usage and suboptimal efficiency of IT resources. However, the (unwanted) usage of non-renewable energies could not have been validated as a trigger for Green Incidents. In respect of the proposed measures the delay of services provided and the usage of progressive charging rates were of potentially high significance. In respect to the precise design of the Green Incident Management process experts consentaneously found that Green Incidents should be prioritized lower than conventional incidents. The question whether Green Incidents should be worked in a separate sub-process could not fully be answered. According to that, the necessity of an arrangement of the Green SLA as a compulsory requirement for a Green Incident Management remained a topic for further investigation.

The ecological extensions, which have been conducted in this paper, satisfy ecological requirements. Nevertheless, it is of equal importance to preserve the original design objectives of ITSM, which are in particular, process orientation, service orientation, and customer orientation. Taking the example of Incident Management, ecological objectives have received a lower priority than conventional incidents, a fact that has also been approved in the pre-validation. Clearly, this procedure prevents goal conflicts between economic objectives and ecological objectives. Nevertheless, the risk remains that ecological objectives will not be pursued with the same engagement and that the related measures will become ineffective. Advantageous are solutions, which satisfy both requirements, the most prominent example being the increase of resource efficiency. Nevertheless, the derived ecological objectives demand also the substitution of materials and the establishment of demand control, which poses new challenges to traditional thinking. Solutions exist, such as Hart (1995), who provides an example of an American energy supplier which achieved a decrease of total energy demand in cooperation with its customers.

The strengths of the approach can be found in the fundamental deduction of ecological objectives from the concept of sustainability and the definition of appropriate requirements to ITSM. The introduction of Ecology Management as a response to these requirements can be proved by tracing the argumentative-deductive development and by the validation by the ITIL experts. Furthermore, traditional concepts of ITSM, like SLA or Incident have been taken into account and have been adapted in order to prepare a potentially high acceptance rate by IT organizations and their customers. Remaining challenges are the measurement of the effectiveness of the extensions, as well as proving the completeness of the requirements and the model.

One important limitation of this paper is its focus on IT Service Management. The solution does not aim at providing a general solution for Service Engineering and Service Management. A possible generalization remains subject for further research.

Summary and Outlook on Future Work

The objective of this paper was to develop an ecologically oriented extension for IT Service Management, using the method of reference modeling. Therefore, a hierarchy of ecological objectives has been developed from the concept of sustainability. In accordance with related work to ecology, these ecological objectives ask for the substitution of non-renewable resources by renewable resources, the increase of resource efficiency, and the management of demand. Based on these objectives, the requirements for an ecologically extended ITSM have been derived. To respond to these requirements, the process category Ecology Management was introduced to ITSM. The extensions cover adaptions to existing ITSM concepts, like Green Incidents, Green SLAs, or Green Problems. Furthermore, four sub processes have been defined, is correspondence to the four requirement categories, which were derived from the hierarchy of ecological objectives. The sub processes include the required functions and the necessary Green KPIs to enable the treatment of ecological issues in ITSM.

The main objective for future work is the implementation of the proposed process of Ecology Management into an IT organization. This serves at the assessment of its effectiveness in a real-world scenario. Although the conceptual extensions, like Green Incidents or Green SLAs make use of widely accepted procedures of ITSM, a deeper empirical verification is still required, following the proposed evaluation plan. Regarding the four sub processes of Ecology Management, the individual functions like the delay of service provision or excess capacity management require a further refinement. Nevertheless, it could be proved that ITSM is a suitable leverage for the incorporation of ecological objectives into IT organizations. This is even more important when it is considered that research to ecological ITSM is still emerging and the proposition of fundamental extensions to widely-used best practices, like ITIL, has been an open topic. This work is a first contribution for closing this gap.

Acknowledgement: *The research described in this paper was supported by a grant from the German Ministry for Research and Education (BMBF), project name: Green RoSe, support code 01LY1113.*

References

Ahlemann, F., and Gastl, H. 2007. "Process Model for an Empirically Grounded Reference Model Construction," in *Reference Modeling for Business Systems Analysis,* P. Fettke and P. Loos (eds.), Hershey, PA: Idea Group Publishing, pp. 77-97.

Andre, F. J., and Cerda, E. 2005. "On natural resource substitution," *Resources Policy* (30:4), pp. 233-246.

Bartelmus, P. 2003. "Dematerialization and capital maintenance: two sides of the sustainability coin," *Ecological Economics* (46:1), pp. 61-81.

Becker, J., and Schütte, R. 2007. "A Reference Model for Retail Enterprises," in *Reference Modeling for Business Systems Analysis,* P. Fettke and P. Loos (eds.), Hershey, PA: Idea Group Publishing, pp. 182-205.

Brooks, S., Wang, X., and Sarker, S. 2010. "Unpacking Green IT: A review of the existing literature," in *Proceedings of the 16th Americas Conference on Information Systems (AMCIS 2010),* M. Santana, J. N. Luftman and A. S. Vinze (eds.), Lima, Peru, South America, pp. 1-10.

Butler, T. 2011. "Towards a practice-oriented green IS framework," in *Proceedings of the 19th European Conference on Information Systems (ECIS 2011),* V. K. Tuunainen, M. Rossi and J. Nandhakumar (eds.), Helsinki, Finland, pp. 1-12.

Chen, A. J., Watson, R. T., Boudreau, M.-C., and Karahanna, E. 2009. "Organizational Adoption of Green IS & IT: An Institutional Perspective," in *Proceedings of the International Conference on Information Systems (ICIS 2009),* J. F. Nunamaker Jr. and W. L. Currie (eds.), Phoenix, Arizona, USA, pp. 1001-1017.

Cleven, A., Gubler, P., and Hüner, K. M. 2009. "Design alternatives for the evaluation of design science research artifacts," in *Proceedings of the 4th International Conference on Design Science Research in Information Systems and Technology (DESRIST 2009),* Vijay K. Vaishnavi, Sandeep Purao (eds.), Philadelphia, Pennsylvania, USA, pp. 19-27.

Dahlstrom, K., and Ekins, P. 2005. "Eco-efficiency trends in the UK steel and aluminum industries – Differences between resource efficiency and resource productivity," *Journal of Industrial Ecology* (9:4), pp. 171-188.

Daly, H. E. 1990. "Toward some operational principles of sustainable development," *Ecological Economics* (2:1), pp. 1-6.

Dorsch, C., and Häckel, B. 2012. "Matching Economic Efficiency and Environmental Sustainability: The Potential of Exchanging Excess Capacity in Cloud Service Environments," in *Proceedings of the 33rd International Conference on Information Systems (ICIS 2012),* Ming-Hui Huang, Gabe Piccoli, Vallabh Sambamurthy (eds.), Orlando, Florida, USA, pp. 1-18.

Dubey, S., and Hefley, W. E. 2011. "Greening ITIL: Expanding the ITIL Lifecycle for Green IT," University of Pittsburgh, Katz Graduate School of Business, Pittsburgh, pp. 1-8.

Dyer, C. H., Hammond, G. P., Jones, C. I., and McKenna, R. C. 2008. "Enabling technologies for industrial energy demand management," *Energy Policy* (36:12), pp. 4434-4443.

Ehrenfeld, J. R. 2005. "Eco-efficiency," *Journal of Industrial Ecology* (9:4), pp. 6-8.

Erek, K., Schmidt, N.-H., Zarnekow, R., and Kolbe, L. M. 2009. "Sustainability in information systems: assortment of current practices in IS organizations," in *Proceedings of the 15th Americas Conference on Information Systems (AMCIS 2009),* R. C. Nickerson and R. Sharda (eds.), San Francisco, CA, USA, pp. 1-9.

Fettke, P. 2009. "How Conceptual Modeling Is Used," *Communications of the Association for Information Systems (CAIS)* (25:43), pp. 571-592.

Fettke, P., and Loos, P. 2004. "Referenzmodellierungsforschung," *Wirtschaftsinformatik* (46:5), pp. 331-340, in German.

Frank, U. 2007. "Evaluation of Reference Models," in *Reference Modeling for Business Systems Analysis,* P. Fettke and P. Loos (eds.), Hershey, PA: Idea Group Publishing, pp. 118-140.

Galup, S. D., Dattero, R., Quan, J. J., and Conger, S. 2009. "An Overview of IT Service Management," *Communications of the ACM* (52:5), pp. 124-127.

Graedel, T. E. 2002. "Material substitution: a resource supply perspective," *Resources Conservation and Recycling* (34:2), pp. 107-115.

Hart, S. L. 1995. "A Natural-Resource-Based View of the Firm," *The Academy of Management Review* (20:4), pp. 986-1014.

Herva, M., Franco, A., Carrasco, E. F., and Roca, E. 2011. "Review of corporate environmental indicators," *Journal of Cleaner Production* (19:15), pp. 1687-1699.

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

Hochstein, A., Zarnekow, R., and Brenner, W. 2005. "ITIL as Common-Practice Reference Model for IT Service Management: Formal assessment and implications for practice," in *IEEE International Conference on E-Technology, E-Commerce and E-Service,* Hong Kong.

Howard, A. J., and Holmes, J. 2012. "Addressing data center efficiency: lessons learned from process evaluations of utility energy efficiency programs," *Energy Efficiency* (5:1), pp. 137-148.

Kampragou, E., Lekkas, D. F., and Assimacopoulos, D. 2011. "Water demand management: implementation principles and indicative case studies," *Water and Environment Journal* (25:4), pp. 466-476.

Loock, C.-M., Landwehr, J. R., Staake, T., Fleisch, E., and Pentland, A. 2012. "The Influence of Reference Frame and Population Density on the Effectiveness of Social Normative Feedback on Electricity Consumption," in *Proceedings of the 33rd International Conference on Information Systems (ICIS 2012),* Ming-Hui Huang, Gabe Piccoli, Vallabh Sambamurthy (eds.), Orlando, Florida, USA, pp. 1-17.

Loock, C.-M., Staake, T., and Landwehr, J. 2011. "Green IS design and energy conservation: an empirical investigation of social normative feedback," in *Proceedings of the 32nd International Conference on Information Systems (ICIS 2011),* D. F. Galletta and T.-P. Liang (eds.), Shanghai, China, pp. 1-15.

Loos, P., Nebel, W., Marx Gómez, J., Hasan, H., Watson, R., vom Brocke, J., Seidel, S., and Recker, J. 2011. "Green IT: A Matter of Business and Information Systems Engineering?," *Business & Information Systems Engineering* (3:4), pp. 245-252.

March, S. T., and Smith, G. F. 1995. "Design and natural science research on information technology," *Decision Support Systems* (15:4), pp. 251-266.

Murugesan, S. 2008. "Harnessing Green IT: Principles and Practices," *IT Professional* (10:1), pp. 24-33.

Nishant, R., Teo, T., Goh, M., and Krishnan, S. 2012. "Does Environmental Performance Affect Organizational Performance? Evidence from Green IT Organizations," in *Proceedings of the 33rd International Conference on Information Systems (ICIS 2012),* Ming-Hui Huang, Gabe Piccoli, Vallabh Sambamurthy (eds.), Orlando, Florida, USA, pp. 1-18.

Noran, O. 2006. "Using reference models in enterprise architecture: an example," in *Reference modeling for business systems analysis,* P. Fettke and P. Loos (eds.), Hershey, PA: Idea Group Publishing, pp. 141-165.

Office of Government Commerce 2010. *ITIL – Service Strategy*. Norwich: TSO Information & Publishing Solutions.

Otto, B., and Ofner, M. 2010. "Towards a process reference model for information supply chain management," in *Proceedings of the 18th European Conference on Information Systems (ECIS 2010),* Trish Alexander, Marita Turpin and JP van Deventer (eds.), pp. 1-12.

Özlük, Ö., Elimam, A. A., and Interaminense, E. 2010. "Optimum service capacity and demand management with price incentives," *European Journal of Operational Research* (204:2), pp. 316-327.

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

Porter, M. E., and van der Linde, C. 1995. "Green and competitive: Ending the stalemate," *Harvard Business Review* (73:9-10), pp. 119-134.

Pries-Heje, J., Baskerville, R., and Venable, J. R. 2008. "Strategies for design science research evaluation," in *Proceedings of the 16th European Conference on Information Systems (ECIS 2008),* Willie Golden, Thomas Acton, Kieran Conboy, Hans van der Heijden, Virpi Kristiina Tuunainen-paper (eds.), pp. 1-12.

Reiter, M., Fettke, P., and Loos, P. 2012. "Eine systematische Analyse des Einflusses ökologischer Ziele auf das IT-Service-Management," in *Multikonferenz Wirtschaftsinformatik 2012,* D. C. Matteld and S. Robra-Bissantz (eds.), Braunschweig: GITO Verlag, pp. 1545-1557, in German.

Ruth, M. 2002. "Optimal Resource Extraction," in *A handbook on industrial ecology,* R. U. Ayres and L. W. Ayres (eds.), Cheltenham, UK: Edward Elgar Publishing, pp. 223-231.

Scheer, A.-W. 1998. *Business Process Engineering – Reference Models for Industrial Enterprises,* Berlin et al.: Springer.

Schlieter, H., Juhrisch, M., and Niggemann, S. 2010. "The Challenge of Energy Management – Status-Quo and Perspectives for Reference Models," in *Proceedings of the 14th Pacific-Asian Conference on Information Systems (PACIS 2010),* Patrick Y. K. Chau, Chih-Ping Wei, and Han Zhang (eds.), pp. 411-422.

Schmidt, A., Otto, B., and Österle, H. 2011. "A Functional Reference Model for Manufacturing Execution Systems in the Automotive Industry," in *Proceedings of the 10th International Conference on Wirtschaftsinformatik (WI 2011),* Abraham Bernstein and Gerhard Schwabe (eds.), Zurich, Switzerland, pp. 302-311.

Schmidt, N.-H., Erek, K., Kolbe, L., and Zarnekow, R. 2009a. "Towards a Procedural Model for Sustainable Information Systems Management," in *Proceedings of the 42nd Hawaii International Conference on System Sciences (HICSS 42),* Waikoloa, Big Island, Hawaii, USA: IEEE Computer Society Washington, DC, USA, pp. 1-10.

Schmidt, N.-H., Kolbe, L. M., Erek, K., and Zarnekow, R. 2009b. "Sustainable Information Systems Management," *Business & Information Systems Engineering* (1:5), pp. 400-402.

Siau, K., and Rossi, M. 2011. "Evaluation techniques for systems analysis and design modelling methods – a review and comparative analysis," *Information Systems Journal* (21:3), pp. 249-268.

Smeets, E., and Weterings, R., 1999. *Environmental indicators: Typology and overview*. European Environmental Agency, Copenhagen.

Smith, R. A. 2008. "Enabling technologies for demand management: Transport," *Energy Policy* (36:12), pp. 4444-4448.

Software AG 2007. "ITIL V3 reference model," *commercial database for ARIS business architect*.

Tahvonen, O., and Salo, S. 2001. "Economic growth and transitions between renewable and nonrenewable energy resources," *European Economic Review* (45:8), pp. 1379-1398.

Teuteberg, F., and Straßenburg, J. 2009. "State of the art and future research in Environmental Management Information Systems – a systematic literature review," in *Information Technologies in Environmental Engineering, Proceedings of the 4th International ICSC Symposium, ITEE 2009,* I. N. Athanasiadis, A. E. Rizzoli, P. A. Mitkas and J. M. Gómez (eds.), Berlin, Heidelberg: Springer, pp. 64-77.

Thomas, O. 2005. "Understanding the Term Reference Model in Information Systems Research: History, Literature Analysis and Explanation," in *Workshop on Business Process Reference Models (BPRM), in conjunction with the International Conference on Business Process Management (BPM 2005),* Nancy, France, pp. 16-29.

van der Aalst, W., Desel, J., and Kindler, E. 2002. "On the semantics of EPCs: A vicious circle," in *EPK 2002 – Geschäftsprozessmanagement mit Ereignisgesteuerten Prozessketten, Proceedings of the GI Workshop,* M. Nüttgens and F. J. Rump (eds.), Trier, pp. 71-79.

vom Brocke, J. 2007. "Design Principles for Reference Modeling: Reusing Information Models by Means of Aggregation, Specialisation, Instantiation, and Analogy," in *Reference Modeling for Business Systems Analysis,* P. Fettke and P. Loos (eds.), Hershey, PA: Idea Group Publishing, pp. 47-75.

vom Brocke, J., and Buddendick, C. 2006. "Reusable Conceptual Models – Requirements Based on the Design Science Research Paradigm," in *Proceedings of the 1st International Conference on Design Science Research in Information Systems and Technology (DESRIST 2006),* Claremont, California, pp. 576-604.

Wand, Y., and Weber, R. 2002. "Research Commentary: Information Systems and Conceptual Modeling – A Research Agenda," *Information Systems Research* (13:4), pp. 363-377.

Watson, R. T., Boudreau, M.-C., and Chen, A. J. 2010. "Information Systems and Environmentally Sustainable Development: Energy Informatics and New Directions for the IS Community," *MIS Quarterly* (34:1), pp. 23-38.

Watson, R. T., Lind, M., and Haraldson, S. 2012. "The Emergence of Sustainability as the New Dominant Logic: Implications for Information Systems," in *Proceedings of the 33rd International Conference on Information Systems (ICIS 2012),* Ming-Hui Huang, Gabe Piccoli, Vallabh Sambamurthy (eds.), Orlando, Florida, USA, pp. 1-16.

World Commission on Environment and Development 1987. "Report of the World Commission on Environment and Development: Our Common Future," retrieved 2011/11/07, from http://www.un-documents.net/wced-ocf.htm.