# Development of Design Principles for Boundary Objects in Enterprise Transformation

DISSERTATION
of the University of St. Gallen,
School of Management,
Economics, Law, Social Sciences
and International Affairs
to obtain the title of
Doctor of Philosophy in Management

submitted by

**Ralf Abraham**
from
Germany

Approved on the application of

**Prof. Dr. Robert Winter**
and
**PD Dr. Joachim Schelp**

Dissertation No. 4321

(Difo-Druck GmbH, Bamberg 2015)

The University of St. Gallen, School of Management, Economics, Law, Social Sciences and International Affairs hereby consents to the printing of the present dissertation, without hereby expressing any opinion on the views herein expressed.

St. Gallen, October 22, 2014

The President:

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# Vorwort

Diese Dissertation ist im Rahmen meiner Tätigkeit als wissenschaftlicher Mitarbeiter und Doktorand am Institut für Wirtschaftsinformatik der Universität St. Gallen entstanden. Durch die Unterstützung einer Vielzahl von Personen war es mir möglich, die Dissertation erfolgreich abzuschliessen.

An erster Stelle danke ich meinem Doktorvater, Prof. Dr. Robert Winter, für seine persönliche Betreuung, durchgängige Unterstützung sowie die Schaffung exzellenter Rahmenbedingungen für die Forschung. Darüber hinaus danke ich PD Dr. Joachim Schelp für die Übernahme des Koreferats und seine konstruktive Kritik im Laufe des Dissertationsprozesses.

Besonderer Dank gebührt meinem Arbeitsbereichsleiter Prof. Dr. Stephan Aier für seine kontinuierliche Unterstützung im Rahmen gemeinsamer Publikations- und Praxisprojekte und die hervorragende Heranführung an die wissenschaftliche Arbeitsweise. Des Weiteren danke ich Prof. Dr. Tobias Mettler für sein wertvolles Feedback zur Integration der einzelnen Beiträge in die Dissertation.

Entscheidend zum Erfolg dieser Dissertation beigetragen hat das gemeinsame Forschungsprojekt „A Design Theory for Architectural Coordination of Enterprise Transformation“ mit den Kollegen des Centre de recherche public Henri Tudor in Luxemburg. Ich bedanke mich insbesondere bei Hella Faller und Dr. Sybren de Kinderen für die hervorragende Zusammenarbeit, die auch zu einer gemeinsamen Publikation führte (Paper C). Ich danke auch dem Schweizerischen Nationalfonds (SNF) für die Unterstützung dieses Projektes.

Auch aus dem angewandten Forschungsprojekt „Common Controller Cockpit“ in Kooperation mit Kollegen der ETH Zürich und der schweizerischen Flugsicherung skyguide sind wichtige Ergebnisse in diese Dissertation eingeflossen. Ich bedanke mich insbesondere bei Pablo Breitenmoser und Dr. Markus Eurich von der ETH Zürich sowie bei Prof. Dr. Tobias Mettler für die ausgezeichnete Zusammenarbeit, aus der unter anderem eine gemeinsame Publikation entstand (Paper A). Mein ausgesprochener Dank gilt auch Martin Lüthi, dem Programmleiter auf Seiten von skyguide, für den Zugang zu einer äusserst spannenden Branche und die jederzeit sehr angenehme und erfolgreiche Zusammenarbeit. Ich danke auch der Kommission für Technologie und Innovation (KTI) für die Unterstützung dieses Projektes.

Überhaupt kann praxisorientierte Forschung nicht ohne Unternehmenspartner durchgeführt werden. Ich bedanke mich bei den Mitgliedern des Competence Center Corporate Intelligence für die sehr angenehme und erfolgreiche Zusammenarbeit.

Meine Zeit in St. Gallen wurde auch und vor allem durch meine Kollegen am Institut geprägt. Ich danke Euch allen für die wunderbare gemeinsame Zeit, in der Ihr für mich wahrlich zu Kollegen im schweizerdeutschen Sinne des Wortes geworden seid. Gerne denke ich an gemeinsame Abende und sportliche Aktivitäten, im Sommer wie im Winter, zurück. Insbesondere unsere gemeinsamen Ausflüge und Reisen, ob in die Westschweiz oder ins Tessin, nach Frankreich, Italien oder Österreich, werden mir in bester Erinnerung bleiben.

Ich danke ganz besonders all denjenigen, die durch fachliche Diskussionen, konstruktive Kritik und aufmerksames Gegenlesen, sowohl der einzelnen Beiträge (Teil B) als auch der Zusammenfassung (Teil A), massgeblich zur Qualität der gesamten Dissertation beigetragen haben.

Mein grösster persönlicher Dank gilt schliesslich meinen Eltern Elisabeth und Hans Abraham für den uneingeschränkten Rückhalt, den sie mir immer gegeben haben. Sie haben mich jederzeit bedingungslos unterstützt und mir jede erdenkliche Hilfe zukommen lassen. Dieses Umfeld hat mir die Kraft und das Durchhaltevermögen gegeben, um die Dissertation innerhalb der geplanten dreieinhalb Jahre erfolgreich abschliessen zu können. Euch widme ich diese Arbeit von ganzem Herzen.

St. Gallen, im Januar 2015 Ralf Abraham

# Papers

Paper A Breitenmoser, P., Abraham, R., Eurich, M., and Mettler, T. 2013. "Why Innovation In Air Navigation Services Is So Difficult In Europe? - A Study Identifying Current Obstacles And Potential ICT Enablers," in *ECIS 2013 Completed Research,* Utrecht, The Netherlands, Paper 138.

Paper B Abraham, R. 2013. "Enterprise Architecture Artifacts as Boundary Objects - A Framework of Properties," in *ECIS 2013 Completed Research*, Utrecht, The Netherlands, Paper 120.

Paper C Abraham, R., Niemietz, H., de Kinderen, S., and Aier, S. 2013. "Can boundary objects mitigate communication defects in enterprise transformation? Findings from expert interviews," in *Proceedings of the 5th International Workshop on Enterprise Modelling and Information Systems Architectures (EMISA 2013)*, R. Jung and M. Reichert (eds.), St. Gallen, Switzerland, pp. 27-40.

Paper D Abraham, R., Aier, S., and Winter, R. forthcoming. "Crossing the line: overcoming knowledge boundaries in enterprise transformation," accepted for publication in *Business & Information Systems Engineering*.

Paper E Abraham, R. forthcoming. "Design principles for turning architectural models into boundary objects," accepted for publication in *Architectural Coordination of Enterprise Transformation*, H.A. Proper, R. Winter, S. Aier and S. de Kinderen (eds.), Berlin, Heidelberg, Germany: Springer.

Paper F Abraham, R., Aier, S., and Winter, R. forthcoming. "Fail Early, Fail Often: Towards Coherent Feedback Loops in Design Science Research Evaluation," accepted for publication in *Proceedings of the International Conference on Information Systems (ICIS 2014)*, Auckland, New Zealand.

# Summary of contents

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# List of abbreviations

| | |
|---|---|
| DSR | Design Science Research |
| EA | Enterprise Architecture |
| EAM | Enterprise Architecture Management |
| ERP | Enterprise Resource Planning |
| ET | Enterprise Transformation |
| IS | Information Systems |
| IT | Information Technology |
| RQ | Research Question |

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# Abstract

Enterprise transformation means change that fundamentally affects large parts of an enterprise. Reaching a shared understanding on the goals, plans, and challenges encountered is critical for success, yet remains challenging due to the extraordinarily high diversity of the involved stakeholder groups. This research aims at helping stakeholder groups in enterprise transformation to reach a shared understanding. The approach of enterprise architecture management seems promising for this task, as it deals with describing current and future states, as well as guiding change on an enterprise level. This research draws on the boundary object construct from sociology to describe objects (e.g., architectural models) that establish common ground between diverse stakeholder groups, yet allow those groups to retain their distinct identity.

This research follows the design science paradigm and intends to establish shared understanding in enterprise transformation via architectural models. First, literature is analysed to extract a set of boundary object properties that are potentially relevant for enterprise transformation. Second, these properties are mapped to syntactic, semantic, and pragmatic capacities—which properties enable which capacity? Third, some exemplary design principles are derived to provide actionable and rapidly implementable advice to practitioners.

This research contributes to the theory on boundary objects and architectural models, by demonstrating the applicability of these concepts in an enterprise transformation context. Researchers may use the design principles to study the mutual effects of boundary objects and enterprise transformation, using a sociomaterial perspective. For practitioners, this research provides insight into the effect of architectural models on shared understanding, and guidance on purposeful model design.

*Keywords:* Boundary objects, Enterprise architecture management, Enterprise transformation, Knowledge boundaries, Modelling

# Kurzfassung

Der Begriff Unternehmenstransformation bezeichnet fundamentale Veränderungen, die einen Grossteil des Unternehmens betreffen. In dieser Situation ist es wichtig, ein gemeinsames Verständnis in Bezug auf Ziele, Pläne und Herausforderungen herzustellen. Aufgrund der aussergewöhnlich hohen Diversität zwischen den involvierten Anspruchsgruppen ist dies jedoch eine grosse Herausforderung. Ziel dieser Arbeit ist es daher, den betroffenen Anspruchsgruppen bei der Schaffung eines gemeinsamen Verständnisses zu helfen. Der Ansatz des Unternehmensarchitekturmanagements erscheint hierfür geeignet, da er sich mit der Beschreibung aktueller und zukünftiger Zustände des Unternehmens sowie der Führung von Veränderungen auf Gesamtunternehmensebene beschäftigt. Diese Arbeit stützt sich auf das „Boundary Object"-Konstrukt aus der Soziologie, um Objekte wie etwa architektonische Modelle zu beschreiben, die zwar eine gemeinsame Basis zwischen verschiedenen Anspruchsgruppen schaffen, diese Gruppen aber gleichzeitig ihre eigenständige Identität bewahren lassen.

Da diese Arbeit Unternehmen bei der Etablierung eines gemeinsamen Verständnisses durch architektonische Modelle helfen soll, wird ein gestaltungsorientiertes Paradigma gewählt. Zunächst werden Eigenschaften aus der Literatur über Boundary Objects ermittelt, die in Unternehmenstransformationen potenziell relevant sind. Daraufhin werden diese Eigenschaften zu syntaktischen, semantischen und pragmatischen Kapazitäten in Beziehung gesetzt—welche Eigenschaften ermöglichen welche Kapazitäten? Schliesslich werden einige exemplarische Gestaltungsprinzipien abgeleitet, um schnell umsetzbare, praktische Handlungsempfehlungen zur Verfügung zu stellen.

Diese Arbeit leistet einen Beitrag zur theoretischen Betrachtung von Boundary Objects und architektonischen Modellen, indem die Anwendbarkeit dieser Konzepte im Kontext von Unternehmenstransformationen demonstriert wird. Wissenschaftler können die Gestaltungsprinzipien nutzen, um den wechselseitigen Einfluss zwischen Boundary Objects und Unternehmenstransformationen mittels einer soziomateriellen Perspektive zu untersuchen. Praktikern zeigt diese Arbeit auf, wie sich architektonische Modelle auf die Schaffung eines gemeinsamen Verständnisses auswirken und wie Modelle zielgerichtet gestaltet werden können.

*Stichworte:* Boundary Objects, Knowledge Boundaries, Modellierung, Unternehmensarchitekturmanagement, Unternehmenstransformation

# Part A: Research summary

# 1 Introduction

The information systems (IS) discipline deals with information technology (IT) and its application in business solutions (Benbasat and Zmud 2003, p. 184). In contrast to related disciplines like computer science, IS studies both the actual IT artefact and its key antecedents and consequences in the organizational world. The IS discipline is thus positioned at the "confluence of people, organizations, and technology" (Hevner et al. 2004, p. 75). Two major research paradigms can be identified within IS research: the behavioural paradigm, which strives at understanding the antecedents to and the consequences of IS application, and the design science paradigm, which strives at using this knowledge to purposefully manipulate IS to achieve desirable business goals (Hevner et al. 2004; Winter 2008).

This research follows the design science paradigm: the objective is to generate a set of principles for the design of boundary objects. Boundary objects help to establish shared understanding in enterprise transformation (ET). In other words, this research extends beyond artefact construction (design principles for boundary objects) into the application in a business solution (establishing shared understanding in ET). By focusing equally on both material, constructional properties of boundary objects and their social context or use, this research heeds calls in literature that criticize a bias towards the social at the cost of the material in IS research (Orlikowski and Iacono 2001; Yoo 2013).

## 1.1 Motivation

ET is a relevant and current problem for many enterprises (Abraham 2013; Abraham et al. 2012). Enterprises face an increasingly complex environment which forces them to change fundamentally (Purchase et al. 2011; Rouse 2005b). The root causes for such fundamental change include the emergence of new technologies, changing regulatory requirements, or mergers and acquisitions. This research follows the definition of Rouse (2005b) and uses the term "enterprise transformation" to describe change that fundamentally alters an enterprise's relationship with one of its key constituencies, such as employees, suppliers, customers or investors.

Unlike local change, ET impacts multiple parts of the enterprise (Rouse 2005a). The diversity of the affected domains is reflected in the diversity of the affected stakeholder groups: ET is a collaborative endeavour of diverse stakeholder groups such as enterprise architects, project/program/portfolio managers, or managers of the affected business units. This diversity manifests itself in different knowledge, values, and goals. The need for collaboration among diverse communities of practice is well-recognized in organizational literature (Carlile 2004; Karsten et al. 2001; Nicolini et al. 2012). To enable and support collaborative efforts during ET, a key success factor for the involved communities of practice is communication and to establish shared understanding on transformation goals and each other's plans and objectives.

Among several approaches to improve organizational communication, enterprise architecture management (EAM) has frequently been mentioned as supporting different communities in establishing shared understanding (Simon et al. 2013; Tamm et al. 2011; van der Raadt et al. 2010). EAM refers to the process of shaping and manipulating an enterprise architecture (EA) in a controlled way (Lankhorst 2013; Radeke 2011). Put differently, EAM translates an enterprise's strategy into concrete business processes and supporting IS (Lange et al. 2012).

To better understand how communication can be supported via artefacts—in this research architectural models—the concept of boundary objects is used. Boundary objects provide interfaces among different communities of practice and are considered "a useful theoretical construct with which to understand the coordinative role of artefacts in practice" (Lee 2007, p. 308). The boundary object concept has been widely used in IS literature to analyse the role of IT artefacts and models for communication among communities of practice (Karsten et al. 2001; Levina and Vaast 2005; Pawlowski and Robey 2004). By supporting communication and translation among the diverging perspectives of different communities, boundary objects provide a common frame of reference and help to establish shared understanding.

## 1.2 Problem description

To establish shared understanding among communities of practice in ET is the problem this research is going to address: shared understanding is frequently mentioned as an important antecedent to successful ET (Bisel and Barge 2010; Elving 2005; Ford and Ford 1995; Stensaker et al. 2008). Conversely, defects in communication and thus differences in understanding are a major threat to successful ET (Niemietz et al. 2013), as they lead to delays in transformation, increases in costs, and ultimately to struggles or even failure of ET (Ford and Ford 1995; Harmsen et al. 2009). In this research, shared understanding shall be defined in line with Cohen and Gibson (2003, p. 8) as the "degree of cognitive overlap and commonality in beliefs, expectations, and perceptions about a given target". This definition is also used in recent work on boundary objects and shared understanding (Rosenkranz et al. 2014, p. 307). The scope of this research shall be further specified as follows. (1) This research covers ET, not localized, routine changes. In ET, many communities of practice are involved that greatly differ in their language, knowledge, and values. The ET projects regarded are planned, top-down driven, and large enough to warrant efforts into supporting communication via architectural models. (2) This research primarily investigates objects, in particular architectural models. It is, however, recognized that boundary objects are not sufficient for translating among communities of practice, but that human boundary spanners need to be involved as well. (3) In enterprises, there is a network of boundary objects and boundary spanners that work together to coordinate actions. To support an ET, this research focuses on those few boundary objects that are recognized across the enterprise. Consequently, objects that are used across few communities in an isolated domain of the enterprise during daily operations (i.e., running the business), are not central to this investigation.

## 1.3 Assumptions

Without assumptions, complex phenomena in the social sciences could not be tackled (Ackoff 1979). Therefore, the following assumptions are made.

### 1.3.1 Assumption one

*Boundary objects are a means of translating among the perspectives of diverse communities of practice.*

A boundary object perspective is taken to concentrate on the translation aspect among communities of practice. The central quality attributes are not formal correctness, verifiability, or compliance to external regulations (documentation), but a capacity to translate among the perspectives of diverse communities of practice. Currently, architectural models are often not understood by stakeholders outside the IT departments (Gartner Inc 2012). Architectural models often fail to address the language and concerns of communities of practice such as business unit managers, or program and project managers. Therefore, the properties of existing boundary objects (i.e., of objects that have already been analysed as boundary objects in other domains) shall first be identified.

### 1.3.2 Assumption two

*Shared understanding among communities of practice is enacted during practice.*

This assumption states that focusing on material properties of models is not sufficient for establishing shared understanding. Instead, social aspects of boundary objects, like their incorporation into everyday practices and interventions by human actors, must be considered equally. Human actors can act as “boundary spanners”, i.e., as organizational actors tasked with transmitting and translating information from one community of practice to another (Hawkins and Rezazade M 2012). Employees who act as boundary spanners perform liaison roles among different communities of practice. For example, an enterprise architect performs a liaison role between business and IT communities. Boundary spanning demands great personal communication skills. On the downside, boundary spanners risk to become marginalized—they may not be considered legitimate members of either community of practice (Levina and Vaast 2005). Without considering social aspects like the importance of boundary spanners, boundary objects may be relegated to “designated boundary objects” instead of “boundary objects-in-use” (Levina and Vaast 2005, p. 342).

### 1.3.3 Assumption three

*A semiotic perspective describes the distance between communities of practice.*

Semiotics is the study of signs and sign processes and their usage in communication (i.e., conveying of information). Im and Rai argue that the “concept of boundary objects is grounded in semiotic theory” (2008, p. 1285). Boundary objects can be perceived as sign systems that help communities of practice to construct meaning. Depending on the differences in language, knowledge, and values, this meaning has to be constructed at different semiotic levels.

When trying to establish shared understanding among diverse communities of practice, the degree of difference between the knowledge, language, values and political interests of the communities involved is likely to have an influence on the design of the boundary object. The construct of knowledge boundaries as introduced by Carlile (2002; 2004), which examines differences in knowledge on the three levels of classic semiotics (syntax, semantics, and pragmatics), allows to assess to what degree communities of practice differ. Do they differ merely on a syntactic level, i.e. are they using different signs for the same things, or do they differ on a pragmatic level by pursuing different interests that can only be consolidated via a process of negotiation and knowledge transformation? Since different boundary objects with varying capacities are required to overcome each of the three knowledge boundaries, this differentiation can provide valuable hints on whether a given model is able to bridge the gap between a given set of communities.

There are other frameworks to analyse the role of communication in IS, such as the language action perspective (Winograd and Flores 1986), the communication for action perspective (Goldkuhl 2003), or Goldkuhl's socio-pragmatic framework (Goldkuhl 2005). However, semiotics has been found to be the most feasible alternative for this research, since it focuses on both the structure of signs and on their interpretations. Organizational scholars advocate to view "social and technological systems in organizations in concert" (Zammuto et al. 2007, p. 752). In a similar vein, a research stream called "sociomateriality" has gained momentum in recent years (Doolin and McLeod 2012; Orlikowski and Scott 2008). This research stream assumes an inseparability of the social from the material, calling for an integrated view on artefacts as sociomaterial manifestations. The semiotic perspective is therefore well compatible to the focus on both the design and the management of boundary objects. In a similar vein, Goldkuhl and & Agerfalk (2002) conclude that the semiotic perspective offers a possibility to understand IS "in a deeper sense than as just one kind of technical artifact" (2002, p. 1).

## 1.4 Objectives of the solution

The objective of this research is to develop a set of design principles for constructing and managing boundary objects. What are the properties that make boundary objects successful, and how can these properties be applied to architectural models? This research focuses on the communication aspect of models (and less on modelling concerns such as formal correctness, computability, or executability).

While design principles have been referred to as "knowledge contribution" types (Gregor and Hevner 2013, p. 348), and "[p]rinciples of form and function" as part of an IS design theory (Gregor 2006, p. 329), a precise definition remains elusive. Also, there is no consensus on whether to regard design principles as theory (Gregor 2006, p. 314), or not (March and Smith 1995, p. 255). In this research, design principles are regarded as similar to a "technological rule", and the definition of van Aken is adopted: "a chunk of general knowledge, linking an intervention or artifact with a desired outcome or performance in a certain field of application" (2004, p. 228).

The envisioned design principles for turning architectural models into boundary objects have the properties mentioned in this definition: they shall be generally applicable within the defined scope (i.e., applicable in ET contexts, but not restricted to a certain type of ET or a certain type of enterprises), they shall be invasive (i.e., applying them affects the form and use of boundary objects), and they shall be applied to achieve a desired outcome (i.e., establishing shared understanding among communities of practice in ET).

## 1.5 Research questions

The following research questions (RQs) are directed both at understanding the problem, and at designing and evaluating a possible solution (see Table 1).

*Table 1: Research questions*

| | | |
|---|---|---|
| Generalized requirements and generalized solution components | RQ 1.1 | What are communication-related obstacles in ET? |
| | RQ 1.2 | Which boundary object properties are relevant in ET? |
| Artefact design process | RQ 2.1 | How can syntactic, semantic, and pragmatic boundary object capacities be enabled? |
| | RQ 2.2 | How can design principles for boundary objects be constructed? |

Research question one (RQ 1) covers the problem space and the solution space on a high level of abstraction. In terms of an explanatory design theory (Baskerville and Pries-Heje 2010), generalized requirements from the problem space are identified in RQ 1.1, and generalized solution components are identified in RQ 1.2. The generalized requirements are communication-related obstacles to ET, and the generalized solution components are boundary object properties that are relevant in an ET context.

Research question two (RQ 2) covers the artefact design process and also consists of two sub-RQs. In RQ 2.1, a shift to a lower level of abstraction (compared to RQ 1) is performed. This RQ drills down on both the generalized requirements and the generalized solution components: on the former by focusing on the ET obstacle of (missing) shared understanding, and on the latter by showing how syntactic, semantic, and pragmatic boundary object capacities can be enabled by specific boundary object properties. In RQ 2.2, the artefact construction process is covered, and design principles for a semantic capacity are formulated. Moreover, the entire design process is evaluated, from the identification of generalized problem requirements and solution components, up to the construction of the artefact.

## 1.6 Research design

To address the RQs, this research follows a design science research (DSR) approach. The problem at hand—establishing shared understanding in ET—can be handled by a DSR approach for two reasons: First, it is a field problem, arising from a practitioner's need. Second, the goal of this research is not just to establish shared understanding within one specific enterprise, but instead to develop a generally-applicable set of principles for creating and maintaining boundary objects. DSR artefacts are expected to not just solve a single problem in a specific enterprise, but to provide solutions for a generic class of problems (van Aken and Romme 2009; Winter 2008).

This research strives to be of practical relevance, but the notion of relevance that is aimed at needs to be clarified. Nicolai and Seidl (2010) distinguish three notions of relevance—instrumental, conceptual, and legitimative relevance. Instrumental relevance is the most prominent notion of relevance—knowledge that influences future courses of action. Conceptual relevance may be attributed to knowledge that modifies our understanding of a decision situation. Instrumental relevance, finally, may be attributed to knowledge that is useful in justifying a decision, providing legitimacy and credibility to decision-makers.

The artefact to be developed in this research possesses both instrumental and conceptual, and to some degree also legitimative relevance: by providing design principles for boundary objects, practitioners can guide the evolution of architectural models towards boundary objects (instrumental relevance). By introducing the very notion of boundary objects, along with antecedents and prospective outcomes in enterprises, practitioners gain a deeper understanding on the importance and challenges of establishing shared understanding (conceptual relevance). By using the notion of boundary objects in internal discussions, practitioners may gain additional credibility when outlining the requirements for a specific model design that works as a boundary object (legitimative relevance). By addressing relevance notions other than instrumental relevance, this research responds to a research gap, namely that "management scholars strive too much for immediate, instrumental relevance and tend to overlook the importance of conceptual relevance" (Nicolai and Seidl 2010, p. 1277).

For constructing the solution, the boundary object concept and EAM are central. Both have been discussed extensively in literature and applied in numerous practical contexts (for an overview of boundary object and EAM application, see Abraham (2013) and Simon et al. (2013), respectively). On the other hand, the problem to be solved is characterized by a low domain maturity, as seen from the multitude of failing ET projects and the scarcity of supporting approaches. By applying a solution with a high maturity to an application domain with a low maturity, this research is positioned in the exaptation sector (Gregor and Hevner 2013).

Reference DSR processes are provided by multiple authors (e.g., Hevner et al. 2004; Nunamaker Jr et al. 1991; Peffers et al. 2007). For an overview and comparison, see Peffers et al. (2006, p. 91). In this research, the established DSR methodology from Peffers et al. (2007) is used, which consists of six activities: Identify Problem & Motivate, Define Objectives of a Solution, Design & Development, Demonstration, Evaluation, and Communication. The communication activity is performed in parallel to the other five activities by publishing intermediate results from this research. The connection between the RQs and the activities of the DSR methodology are presented in Figure 1.

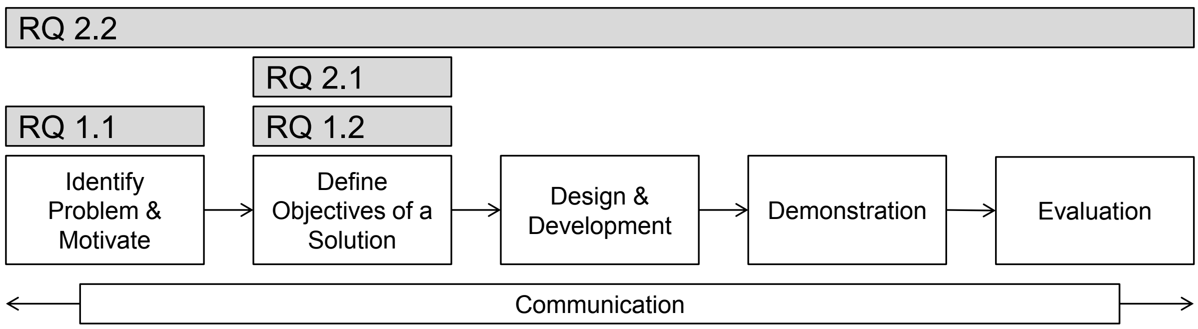


*Figure 1: Connection between research questions and the DSR methodology process model (based on Peffers et al. 2007, p. 54)*

## 1.7 Structure of the dissertation

This dissertation consists of two parts: Part A provides an overall summary of the work, starting with an introduction in section one, conceptual foundations in section two, related work in section three, an overview of the results in section four, and a summary in section five. Part B consists of the scientific papers that have been published in the course of this research.

Part A, section one starts with a motivation of the overall research project (section 1.1), a description of the specific problem to be addressed (section 1.2), the assumptions made and the objectives of the solution (section 1.3 and section 1.4), the derived RQs (section 1.5), the overall research design (section 1.6), and this section (section

1.7) on the structure of the dissertation. Section two discusses the conceptual foundations of this research: first, the focal constructs of this research (section 2.1); second, foundations from the problem and solution domains of ET/EAM and their interplay (section 2.2); finally, justificatory knowledge on communication and use (section 2.3). Section three gives an overview of the state of the art concerning boundary objects (section 3.1), model-based support of ET (section 3.2), and a synthesis (section 3.3). Section four provides an overview of the results: first, how each paper contributes to answering the RQs (section 4.1); second, the results themselves (section 4.2); finally, a reflection on the design principle construction process (section 4.3). Section five discusses the contribution and limitations of this research (section 5.1), and derives implications for theory (section 5.2) and practice (section 5.3).

Part B, the publications part, consists of the scientific papers which jointly address the RQs formulated in Part A (section 1.5). The papers have been re-formatted to ensure consistency in presentation. Specifically, a uniform citation style has been applied to all papers, all tables and figures have been numbered continuously, and all references have been merged into a single list at the end of the dissertation. Each paper is preceded by its bibliographical metadata and abstract. The metadata include the following attributes: title, author(s), selected approach for order of authors, publication outlet, publication type, publication year, rating (based on the Jourqual 2.1 ranking (Verband der Hochschullehrer für Betriebswirtschaft 2011)), and publication status.

# 2 Conceptual foundations

In this section, the focal constructs of this research, the problem and solution domains of ET and EAM (including their interrelationships), as well as "justificatory knowledge" (Gregor and Jones 2007, p. 324) from the areas of communication and use literature are introduced.

## 2.1 Focal constructs

### 2.1.1 Communities of practice

"Community of practice" is a term coined by Wenger (2000) to describe a self-selecting and self-organizing community of people that (1) share a joint area of concern, (2) interact regularly, and (3) possess a shared repertoire of resources such as languages, methods, tools, or other common artefacts. In this research, a community of practice is considered as a group of intra-organizational stakeholders concerned with ET (i.e., people that have a common concern during a transformation project, like IT architects or project managers). The concept of "practice" is not understood as a contrast to theory, but as a set of "recurrent activities" (Orlikowski and Scott 2008, p. 462). For further details on communities of practice, see Paper B and Paper D.

### 2.1.2 Boundary objects

The term "boundary object" was originally introduced by Star and Griesemer (1989). Boundary objects are artefacts that support knowledge sharing among different communities of practice by providing a common frame of reference. This research adopts the definition of Winter and Butler (2011, p. 103): "[b]y identifying 'lowest common denominators,' critical points of agreement, or shared surface referents, boundary objects provide a sufficient platform for cooperative action – but they do so without requiring the individuals involved to abandon the distinctive perspectives, positions, and practices of their 'base' social world".

Further details on boundary objects can be found in Paper B, Paper C, and Paper E. In Paper B, the concept is central to a structured literature review. In Paper C, there is an additional discussion on the interplay between boundary objects and boundary spanners (i.e., human actors with liaison tasks among different communities of practice). In Paper E, boundary objects are set apart from other types of objects that are encountered in collaboration among diverse communities of practice.

### 2.1.3 Knowledge boundaries

The degree of difference among communities of practice in terms of knowledge, goals, and underlying assumptions can be expressed via the construct of knowledge boundaries. Carlile (2004) distinguishes three progressively complex knowledge boundaries—syntactic, semantic, and pragmatic. Syntactic knowledge boundaries are boundaries of information processing, semantic knowledge boundaries are boundaries of interpretation, and pragmatic knowledge boundaries are boundaries of politics. Only after shared understanding has been established at a given knowledge boundary can knowledge be shared via processes of knowledge transfer (at a syntactic knowledge boundary), knowledge translation (at a semantic knowledge boundary), and knowledge transformation (at a pragmatic knowledge boundary) (Carlile 2004; Rosenkranz et al. 2014).

Boundary objects must possess adequate capacities to establish shared understanding at syntactic, semantic, and pragmatic knowledge boundaries. Yet, boundary objects alone are only sufficient at syntactic knowledge boundaries. At more complex semantic and pragmatic boundaries, boundary objects must be complemented by the abilities of their users to properly apply them. Therefore, a boundary spanning capability at a given knowledge boundary consists of both the capacity of the boundary object, as well as the capability of its user (who acts as a boundary spanner or knowledge broker (Rosenkranz et al. 2014, p. 311)). For further details on knowledge boundaries and the capacities required for crossing them, see Paper C, Paper D, and Paper E.

## 2.2 Problem and solution domains

### 2.2.1 Enterprise transformation

Different terms circulate in literature to describe fundamental change in enterprises, ranging from "organizational transformation" (Orlikowski 1996; Romanelli and Tushman 1994) or "business transformation" (Safrudin et al. 2011) to "enterprise transformation" (Rouse 2005b). In this research, the term "enterprise transformation" shall be used to describe fundamental change that affects many diverse communities of practice. While transformation is usually regarded as fundamental, radical (second-order) change in contrast to small-scale, incremental (first-order) change, there is some discrepancy whether transformation occurs suddenly and purposefully (Romanelli and Tushman 1994; Rouse 2005b), or whether it results from a continuum of emergent, smaller changes (Beer et al. 1990; Orlikowski 1996).

Rouse and Baba (2006) name four main drivers for ET: new revenue opportunities induced through emerging markets or new technologies, threats to existing markets or technologies, reacting to competitors' transformation initiatives, and internal crises. Winter (2010) provides a slightly different classification of transformation drivers, distinguishing between business– or IT-driven projects, alignment projects caused by an increasing mismatch between business demand and IT capabilities, as well as ET for creating new potentials and improving connectivity with external partners.

### 2.2.2 Enterprise architecture management

According to the ISO/IEC/IEEE 42010 standard, architecture is defined as "the fundamental organization of a system, embodied in its components, their relationships to each other and the environment, and the principles governing its design and evolution" (ISO/IEC/IEEE 2011). This definition of architecture involves two dimensions: The first part of the definition ("the fundamental organization of a system, embodied in its components, their relationships to each other and the environment […]") forms a descriptive dimension, concerning the structure of the system's building blocks and the relationships between them. The second part ("[…] the principles governing its design and evolution") forms a prescriptive dimension, effectively restricting the design and evolution space of the system under consideration (Dietz and Hoogervorst 2008). In line with The Open Group (2011, p. 5), an enterprise is defined as "any collection of organizations that has a common set of goals". In this definition, the term enterprise has a wider scope than the term "organization", since an enterprise (e.g., "a government agency, a whole corporation, a division of a corporation, [or] a single department") is a composition of one or more organizations.

EAM then refers to the process of shaping and manipulating an EA in a controlled way (Lankhorst 2013; Radeke 2011). EAM translates an enterprise's strategy into concrete business processes and supporting IS (Lange et al. 2012): it "captures all those processes, methods, tools, and responsibilities necessary to build a holistic and integrated view of the enterprise and allow for a continually aligned steering of business and IT" (Simon et al. 2013, p. 2). The benefit most commonly associated with EAM is maintaining a continuous alignment between business processes and their supporting IS (Radeke 2011; Rohloff 2011; Ross 2003; Simon et al. 2013; Simon et al. 2014; Tamm et al. 2011).

In the descriptive aspect of architecture, EAM is concerned with establishing transparency. Transparency means providing an accurate and up-to-date documentation of the structure and interrelationships of an enterprise's building blocks. Transparency is a major antecedent to other EAM activities like planning (Radeke 2011; Tamm et al. 2011), and has been linked to increased organizational alignment. By supplying this information to decision makers, EAM serves as a decision support function by "taking the overwhelming amount of information available and presenting it in a manner that enables effective decision-making" (Strano and Rehmani 2007, p. 392). The "structured description of the enterprise and its relationships" is also called the "fundamental 'management information system' for the enterprise" (Simon et al. 2014, p. 6). In the prescriptive aspect of architecture, EAM provides principles that guide the enterprise's evolution (Dietz and Hoogervorst 2008) by restricting design freedom. The primary goal of principles is to maintain consistency between an enterprise strategy and its implementation (Proper and Greefhorst 2010).

This research concentrates on the descriptive aspect of EAM, namely the transparency goals of EAM that help to generate shared understanding (Simon et al. 2013; Tamm et al. 2011; van der Raadt et al. 2010). For example, when the strategy of an enterprise is decomposed into an architectural model, this model reflects the fundamental choices and assumptions of that enterprise and is therefore seen as a powerful tool to establish shared understanding (Simon et al. 2014, p. 23). The EA artefacts most closely associated with generating transparency are models. These models may describe the current state of the enterprise (as-is models), but also possible future states (to-be models) (Aier and Saat 2011). They are provided across all architectural layers (high breadth) on a high level of aggregation (limited depth) (Winter and Fischer 2007, p. 5 f.).

### 2.2.3 Architectural support of enterprise transformation

EAM is a supplier of information, capable of highlighting dependencies and supporting the coordination of ET (Harmsen et al. 2009; Ross et al. 2006; Tamm et al. 2011). According to Simon et al. (2014, p. 32), EAM is especially valuable in assessing the level of transformation readiness of an enterprise by making complex relationships between business processes and IT systems transparent. Labusch and Winter (2013) conduct an extensive literature review on how EAM supports the needs of ET, and where there are gaps. They conclude that activities in ET that cover a broad, enterprise-wide perspective such as IT landscapes or skillsets in the company are better supported by EAM than individual-level topics such as personal agendas or resistances to change (those are better handled by human-focused management disciplines). Thus, they highlight the information-providing aspect of EAM and emphasize a broad rather than a narrow EAM focus. Still, they conclude that support for the communication aspect in ET is both highly required, but not yet formally or methodically supported.

With regard to the communication aspect of ET, the descriptive aspects of EAM are primarily regarded. Of the EAM elements primarily associated with this part (i.e., models and other documentation artefacts), Winter et al. (2013) consider roadmaps and to-be models as major input for planned ET.

## 2.3 Justificatory knowledge

### 2.3.1 Communication

Communication means the exchange of information between at least two people. Communication may occur through words, in writing, or even by tacit signals. Some authors go as far as stating that any behaviour is some form of communication, and that it is consequently impossible not to communicate (Watzlawick et al. 1967). Communication is often regarded from two distinct perspectives: The traditional perspective, and the dialogic perspective. The traditional perspective emphasizes technological aspects on message transmission, seeing communication as a means to exchange information on an objective reality. The dialogic perspective emphasizes communication as a process of social construction, seeing communication not as transmitting information on an objective reality, but as inextricably linked to constructing reality. Examples for the former, traditional view on communication are the communication model of Shannon (1949), or the conduit model which is based on Shannon´s model (Boland and Tenkasi 1995). Examples for the dialogic view on communication are the speech act theory by Austin (1975) and Searle (1969), Wittgenstein's language games (Wittgenstein 1974), or the language action perspective (Goldkuhl 2003).

In Table 2, the key assumptions and differences between the two views on communication are presented. The traditional view allows for efficient, reliable, and precise transmission of information. Providing a strong syntax and shared meanings may also strengthen enterprise-wide integration (Boland and Tenkasi 1995, p. 361). On the downside, the traditional view is susceptible to disregarding diversity, levelling differences among communities of practice to the point of creating an inappropriate uniformity. The dialogic view, on the other hand, values the diversity among organizational communities. Yet, it bears the risk of increasing conflicts among communities over the construction of reality, and may contribute to increased defragmentation in organizational terminology.

*Table 2: Contrasting the traditional and the dialogic view on communication (based on Boland and Tenkasi (1995))*

| Traditional view | Dialogic view |
|---|---|
| There is an objective reality that is shared by all communities. | Perceptions of reality differ among communities. There is no uniform, objective reality, but reality is constructed by human actors as they communicate. |
| Language is a medium for representing knowledge. | Language is knowledge. |
| With a predefined terminology, people can communicate between each other in an objective way. | The meaning of words that are transmitted shifts depending on context factors. |
| There is universal consensus across communities on the meanings of words. | There is consensus on the meaning of words only within a specific community of practice. |
| Technological capabilities are the primary constraints in communication. | Social and political factors are the primary constraints in communication. |

For diverse communities of practice to work together, a process referred to as "perspective taking" (Boland and Tenkasi 1995, p. 362) is required. Perspective taking occurs when the perspective of one community is reflected against the perspectives of other communities, and when other perspectives are taken "into account", i.e. when knowledge and concerns of other communities are incorporated into the own community´s perspective (Karsten et al. 2001). The traditional view on communication denies the importance of perspective taking altogether. The dialogic view, while acknowledging the socially-constructed nature of communication, makes perspective taking a challenging task nevertheless, because increasingly specialized local meanings and languages within communities may render it impossible to explicate a community´s knowledge to others (Boland and Tenkasi 1995). Yet, without explicating a community of practice's knowledge, the perspective taking process cannot take place. Next to relying on human agents, boundary objects provide a means for explicating a community or practice's knowledge and thus support communication and perspective taking in enterprises.

### 2.3.2 Use

Boundary objects are inextricably linked to use: only an object that is used by different communities of practice in their daily work can become a boundary object. The term "use" shall be reserved to denote the process of usage of an artefact by a certain group of users, rather than an appreciation of a desired outcome by that group. Such a desired outcome shall be referred to as creating "utility" (i.e., being useful, beneficial, creating value) for that user group. Levina and Vaast (2005, p. 342) distinguish "designated boundary objects" from "boundary objects-in-use": only because an object is designated as a boundary object by a certain community of practice, or by senior management, does not mean that this object will automatically be adopted and used as a boundary object. Expressing support for a boundary object by one or several communities may increase this object's momentum, but there is no automatism in the adoption of a boundary object. Boundary objects can generate value only by being used and only during their use. Each time a boundary object is used by communities of practice to establish shared understanding in a specific situation, value is created. Value is not created at the time a boundary object is constructed and stored physically or electronically (construction is a necessary, but not a sufficient condition for value creation).

The idea of an artefact creating impact only by the time it is used is not new. In a nomological net, Benbasat and Zmud position the construct of use (in their terms "usage") between the IT artefact itself and its impact (Benbasat and Zmud 2003, p. 187). Mayer at al. (2012) discuss use scenarios for executive IS. Like boundary objects, such systems generate value by the time they are used, not by the time they are constructed and deployed. Brenner et al. postulate "[u]ser-centric IT design" (2014, p. 60) as a new design perspective for IS. They call for the user to be recognized as an actor (rather than an object of analysis), that influences and is influenced by the design of IT artefacts. In related disciplines like marketing, a paradigm dubbed the "service-dominant […] logic of marketing" (Vargo and Lusch 2008, p. 1) has recently gained momentum. Key assumptions of this paradigm state that value of any service is only created during use, and that use is not context-independent, but varies depending on the involved actors and their concrete use situations (Vargo and Lusch 2008).

The idea of linking the design of artefacts to the context of its use is pushed farthest by a stream of research that is referred to under the umbrella term "sociomateriality". Sociomateriality is a "posthumanist perspective" (Doolin and McLeod 2012, p. 571) that holds as its central tenet the inseparability of the social from the material. Sociomateriality sees all relations between human beings and artefacts as continuously re-enacted in everyday practices (Orlikowski and Scott 2008, p. 461), rather than as statically given. Under this perspective, artefacts must be considered as manifestations, as a "constitutive entanglement" between their constructional properties and their use in specific situations (Orlikowski 2007, p. 1437). A central idea within sociomateriality is the notion of performativity: sociomaterial manifestations do not only describe, but also create reality. MacKenzie and Millo (2003) provide a vivid example of the Black-Scholes model for option pricing. Through its dissemination in academic and then practitioners' publications and its subsequent adoption by finance professionals, this model actually created the market it initially set out to describe. In other words, the market it described did not exist at the time of the model's publication, but came to be enacted in the following years. As MacKenzie and Millo put it, "[o]ption pricing theory—a 'crown jewel' of neoclassical economics—succeeded empirically not because it discovered preexisting price patterns but because markets changed in ways that made its assumptions more accurate and because the theory was used in arbitrage" (2003, p. 107). A similar notion performativity can be found in the theory of speech acts (Austin 1975; Searle 1969), which also claims strong links between speech and action ("performative utterances", e.g. the words "I do" at a wedding, the ceremonial launching of a ship using a certain phrase, or the performance of a secular or religious ceremony).

Boundary objects have been found to share many ontological foundations with sociomateriality (Doolin and McLeod 2012). The boundary object concept also places strong emphasis on use (Levina and Vaast 2005). Considering the boundary object concept against the backdrop of use and the sociomaterial research stream, the following implications are derived for this research. (1) Use-centricity: Boundary objects generate their value during use and only during use. Designing boundary objects is a necessary, but not a sufficient condition for their subsequent use. (2) User intimacy: For enterprise architects, it is crucial to have know-how regarding the processes and challenges on the business side. They need to really understand prospective users' problems to enter a discussion with business communities of practice and to work towards establishing shared understanding. (3) Performativity: The input from various communities of practice will shape the design of the boundary object, but the boundary object (at the time of its use) will also influence the interaction among the communities of practice. Thus, when creating boundary objects, potential communities of practice that will be affected by the boundary object should be involved early in the design process.

# 3 Related work

## 3.1 Boundary objects

Boundary objects have frequently been used in literature to describe interactions among communities of practice in the engineering domain, for example between architects and building constructors (Gal et al. 2008), automobile engineers (Carlile 2004), and design and manufacturing engineers (Bechky 2003; Henderson 1991; Karsten et al. 2001). A prominent example of boundary objects are three-dimensional models such as computer aided design models, due to their malleability. In the IS Domain, boundary objects are a frequently used concept in the field of computer-supported collaborative work (Lee 2007), shared IT systems such as enterprise resource planning (ERP) systems (Pawlowski and Robey 2004), software development (Barrett and Oborn 2010; Levina 2005; Pawlowski and Robey 2004), or electronic business interfaces (Malhotra et al. 2007). The majority of these works are qualitative; describing the adoption and use of boundary objects in various enterprise contexts. However, they rarely give concrete guidance on how to design models. One notable exception is the paper of Karsten et al. (2001), who indicate requirements for the IT support of a virtual community of practice. These requirements include full access by all community members, annotating information with additional detail, readability optimization, and versioning support. Recently, Rosenkranz et al. (2014) have applied the boundary object and knowledge boundary concepts, building on the knowledge boundary framework of Carlile (2004), to examine the interaction of organizational communities of practice during requirement elicitation processes.

As for providing boundary object properties, only Fong et al. (2007) have made explorative attempts and identified a set of six boundary object attributes (type, familiarity, context, granularity, utility, functionality). While a valuable first iteration in identifying properties, this list is not based on a structured review of existing boundary object literature. It also mixes object construction, use and management, and factors like the degree of difference among the involved communities of practice (captured in the attribute "context" and referred to as "mental models of the user groups" (2007, p. 14)).

However, the boundary object concept has also been criticized: several authors have voiced concerns over a tendency of regarding any object that is used by multiple communities of practice as a boundary object, and call for a more differentiated view regarding objects in collaboration (e.g., Lee 2007; Neyer and Maicher 2013; Nicolini et al. 2012). As a response, Nicolini et al. (2012) provide a typology of four different object types in collaboration. They reduce boundary objects to a translation function and thus re-adjust the concept to its original meaning.

In some situations, boundary objects have also been criticized as being detrimental rather than supportive for cooperation. Carlile (2002) states that the boundary object character of artefacts was hard to sustain amidst changing people and problems. The emergence of new knowledge boundaries must be met by appropriate boundary objects to sustainably support communication. Quoting one of his informants, “CAD can be an effective communication tool in one meeting, then a 'bludgeoning tool' in the next” (2002, p. 452). Likewise, Sapsed and Salter (2004) stress that boundary objects need a high degree of maintenance in the form of regular face-to-face meetings among members of the involved communities of practice. Specifically, they point out that project management tools work as boundary objects only if project team members regularly meet in person. In the case of large geographical distance and hence little personal interaction, boundary objects are prone to be ignored. Translating this to the realm of EAM, it means that EA models can act as boundary objects, but only if there is significant personal involvement by the architect (Grinter 1999). Regarding the relationships among the involved communities of practice, Oswick and Robertson (2009) mention the issue of authorship and power relationships: In case of one-sided distribution of power (e.g., relationships between managers and workers), boundary objects may be used to cement the status quo, instead of supporting change. The agendas of community members may also affect the shape of the boundary object: in an ethnographic observation of automotive engineers, Barley et al. (2012) find that individuals would deliberately create ambiguous objects, if they wanted to foster discussions and facilitate the emergence of shared understanding. However, if they wanted to force their own viewpoint on things upon their peers, without discussion, they would deliberately create models that did not allow for shared meanings, but only permitted one interpretation (their own).

## 3.2 Conceptual modelling and enterprise architecture

Just as focusing exclusively on constructional properties of boundary objects, disregarding their management, is regarded as insufficient in the boundary objects literature, a similar tendency can be observed in the literature on architecture. There is a shift from a predominantly structural notion of architecture towards the conception of architecture as language. Smolander et al. (2008) note that architecture used to be predominantly understood with a blueprint metaphor: architecture as structural description of a system, with the aim of guiding future implementation efforts. However, recent works begin to understand architecture as language, suggesting that the “role of architecture is not providing a basis for creation of artefacts; instead, it acts as a facilitator of communication across stakeholder groups” (2008, p. 582). Consequently, “architecture as language directly corresponds to the idea of a boundary object” (2008, p. 582).

In that sense, several authors consider EA artefacts and models as boundary objects (Buckl et al. 2008; Ernst 2008; Pareto et al. 2010; Scheil 2008; Smolander et al. 2008; Valorinta 2011). EA as a whole has also been conceptualized as a boundary object and has empirically been found to improve business-IT alignment (Foorthuis et al. 2010; Schmidt and Buxmann 2011; Tamm et al. 2011; Valorinta 2011). However, these works take a very generic and rather technology-oriented view on EA. In contrast, this research focuses on the descriptive aspect of EA. Moreover, architectural models shall not be designed for business-IT alignment, but for establishing shared understanding in ET.

Work has also been done on models that involve different stakeholders (Stirna and Persson 2012; Stirna et al. 2007). Stirna and Persson (2012) stress the importance of the enterprise modelling process, providing a list of competency requirements for the enterprise modeller and stating that modelling success “depends more on the quality of the process of modelling rather than on the method used” (2012, p. 662). Yet, these works concern collaborative modelling in general, while this research focuses on translating among communities of practice (architecture as language).

McGinnis (2007) discusses the connection between enterprise modelling and ET. He sees potential for enterprise modelling to become a decision support function for ET. He names four aspects of enterprise modelling concepts that are of particular importance during ET: First, to support decision making, enterprise models must speak the language of the decision makers (i.e., business language). Second, models must support multiple levels of problem description. Third, enterprise models must incorporate risk and uncertainty. Fourth, models must not be only technology-centric, but must also strongly involve human aspects (i.e., role descriptions and the activities of the modeller).

Furthermore, work on model quality (Krogstie 2012; Krogstie et al. 2006; Moody 1998; Nelson et al. 2012) provides properties to assess both the process of modelling as well as the resulting model itself (Moody 2005). Krogstie et al. (2006) define quality to not just encompass representational quality, but also a model's capacity to facilitate learning and action. This parallels Carlile's (2002; 2004) discussion of translating knowledge at semantic boundaries (i.e., a process of learning about new differences and dependencies) and transforming knowledge at a pragmatic boundary (i.e., overhauling existing cognitive structures). Nelson et al. (2012) provide an integrated model quality framework that places special emphasis on representational quality. However, the aforementioned works on model quality focus on evaluating the model quality for a single user community. This research focuses instead on the interplay among different communities of practice.

Moody (2009) provides a set of design principles to construct cognitively efficient models. These principles relate to the model's syntax (e.g., visual expressiveness) as well as its semantic (e.g., symbol redundancy, symbol overload). Applying these principles, several modelling languages such as ArchiMate and UML are analysed, and modelling constructs violating the principles of cognitive efficiency are identified. Albeit pragmatic aspects (the process of use and management) are not addressed, it is nevertheless assumed that the visual design principles will play an important role in designing boundary objects.

## 3.3 Synthesis

Regarding the boundary object concept, literature shows that simply concentrating on constructional parameters is not sufficient in ET: in addition to constructional requirements, boundary objects need to be continuously managed. Regarding the literature on conceptual modelling and EA, various model quality criteria are provided. However, these criteria do not explicitly cover an ET context, which is characterized by the high diversity among the involved communities of practice. EA has been discussed as a boundary object in its entirety, yet the boundary object concept is mentioned predominantly in a metaphoric sense in an EA context, rather than applied to provide concrete design guidance. Summarizing, neither the body of boundary object literature, nor the body of conceptual modelling literature could provide a detailed analysis of boundary object properties. Therefore, a structured literature review is conducted in Paper B to arrive at a set of boundary object properties that is at a sufficient level of detail to inform subsequent construction activities.

# 4 Results

## 4.1 Overview

Table 3 shows the connections between the papers included in this research, and the degree to which each papers contributes to answering the overall RQs via its key contribution. The RQs partition the overall design objective into individual chunks that are addressed by one or several papers.

In RQ 1, generalized requirements and generalized solution components are covered. Paper A addresses the first activity in the DSR methodology, "Identify Problem & Motivate", and answers RQ 1.1. Although this work is set in the domain of air navigation services and high reliability organizations, many of the identified obstacles (e.g., limits in technology, social acceptance issues) are encountered in other industries as well. A technological architecture is proposed to overcome obstacles like system interoperability. Next to its immediate technological purpose, this architecture also serves as a boundary object, even without being designated so. The architectural to-be model generates shared understanding on the current situation and the obstacles to ET that need to be faced by that particular company. Based on that shared understanding, solution alternatives can be discussed: "[b]y showing how technological obstacles can be overcome with a concrete architectural proposal that takes specific industry requirements (e.g., security and the need for evolutionary change) into account, the perceived characteristics at the persuasion stage are likely to be convincing from a technological point of view" (Breitenmoser et al. 2013, p. 10 f.).

Therefore, Paper A demonstrates the generalized requirement of establishing shared understanding in ET, and also hints at the boundary object concept as a potential place to search for generalized solution components. Paper B addresses the second activity in the DSR methodology, "Define Objectives of a Solution", by collecting boundary object properties that are relevant in ET. Thus, Paper B collects generalized solution components.

RQ 2 details the generalized requirements towards the specific objective of establishing shared understanding, and elaborates how which generalized solution components enable which boundary object capacity. This is the basis for the subsequent artefact design. Paper C and Paper D address the activity "Define Objectives of a Solution", and answer RQ 2.1 qualitatively (Paper C) and quantitatively (Paper D). Paper E and Paper F together answer RQ 2.2.

*Table 3: Connection between research questions and paper contributions*

| Paper ID / Title / Reference to key contribution in paper | | RQ 1 | | RQ 2 | |
|---|---|---|---|---|---|
| | | RQ 1.1 | RQ 1.2 | RQ 2.1 | RQ 2.2 |
| A | Why Innovation In Air Navigation Services Is So Difficult In Europe? - A Study Identifying Current Obstacles And Potential ICT Enablers<br>Paper A, Figure 7 | ● | ○ | ○ | ◔ |
| B | Enterprise Architecture Artifacts As Boundary Objects - A Framework Of Properties<br>Paper B, Figure 8 | ○ | ● | ○ | ◔ |
| C | Can boundary objects mitigate communication defects in enterprise transformation? Findings from expert interviews<br>Paper C, Table 16 | ○ | ○ | ● | ◔ |
| D | Crossing the line: overcoming knowledge boundaries in enterprise transformation<br>Paper D, Figure 9, Table 19 | ○ | ○ | ● | ◔ |
| E | Design principles for turning architectural models into boundary objects<br>Paper E, Section E.4 | ○ | ○ | ○ | ◑ |
| F | Fail Early, Fail Often: Towards Coherent Feedback Loops in Design Science Research Evaluation<br>Paper F, Section F.4 | ◔ | ◔ | ◔ | ◑ |

Legend

| ○ | ◔ | ◑ | ● |
|---|---|---|---|
| No coverage of RQ | Partial coverage of all RQ aspects | Detailed coverage of single RQ aspects | Full coverage of all RQ aspects |

| | | |
|---|---|---|
| Generalized requirements and generalized solution components | RQ 1.1 | What are communication-related obstacles in ET? |
| | RQ 1.2 | Which boundary object properties are relevant in ET? |
| Artefact design process | RQ 2.1 | How can syntactic, semantic, and pragmatic boundary object capacities be enabled? |
| | RQ 2.2 | How can design principles for boundary objects be constructed? |

Paper E details the artefact construction process, thus focusing on the “Design & Development” activity. Paper F covers the evaluation of both the design process and the design product, by explicating the evaluation aspects contained in the other papers. RQ 2 details the generalized requirements towards the specific objective of establishing shared understanding, and elaborates how which generalized solution components enable which boundary object capacity. This is the basis for the subsequent artefact design.

## 4.2 Papers of the research

In the following subsections, the citation, a synopsis, a summary of the results, a description of the research method, and a reflection on the contribution to the overall research project are provided for each paper included in this cumulative research.

### 4.2.1 Paper A

*Citation*

Breitenmoser, P., Abraham, R., Eurich, M., and Mettler, T. 2013. "Why Innovation In Air Navigation Services Is So Difficult In Europe? - A Study Identifying Current Obstacles And Potential ICT Enablers," in *ECIS 2013 Completed Research,* Utrecht, The Netherlands, Paper 138.

*Synopsis*

The PEST framework is applied to identify political, economic, social, and technological obstacles towards ET. The context is the air traffic management industry in Europe, which is currently undergoing a major transformation. The European Union has formulated ambitious performance targets in terms of capacity and efficiency increase for European air traffic, forcing the organizations in the air traffic management industry to transform their entire business-to-IT stack. In this paper, existing obstacles towards this ET are analysed, and an information and communication technology-based approach focusing on overcoming technological barriers is presented.

*Result*

We identify various political, economic, social, and technological obstacles towards ET in the air traffic management industry. Addressing primarily the technological obstacles, an IT architecture is proposed that fosters a common information model, a chronological decoupling of data production from data consumption, and that makes information in the network (i.e., the European sky) available to all interested participants at the earliest time possible. This architecture blueprint serves two purposes: next to the technological purpose of enabling interoperability between air traffic control centres, it also generates awareness and shared understanding between the involved communities of practice (e.g., air traffic controllers, systems engineers) on the details, constraints, and impact of the planned ET.

Figure 2 shows the target architecture, which serves as a boundary object (without officially being dubbed one) between communities of practice as diverse as air traffic controllers, software developers, and programme managers.

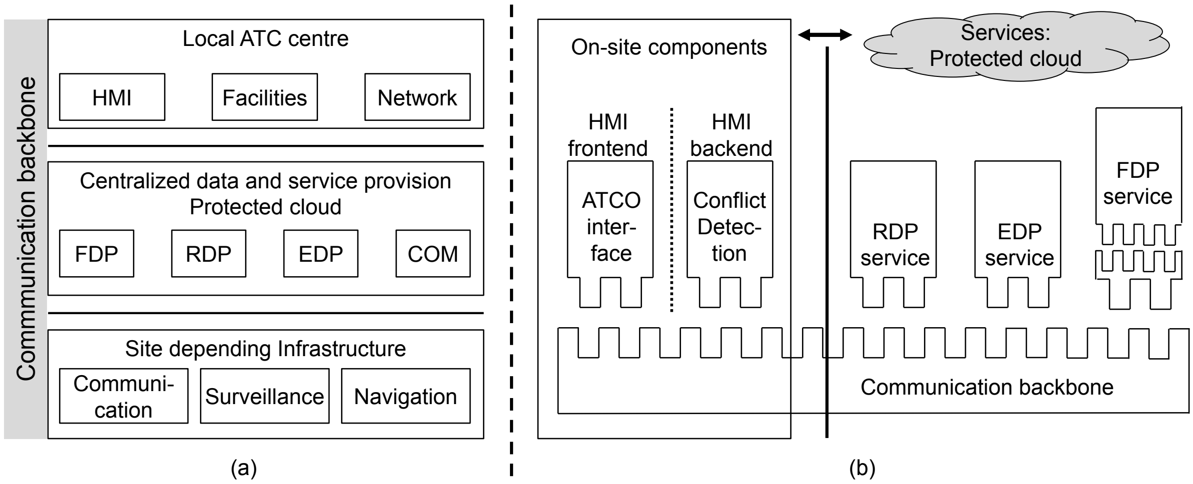


*Figure 2: Target architecture for air navigation service providers (Breitenmoser et al. 2013, p. 10)*

*Research method*

We have conducted a total of 30 interview hours with executives on different levels of the Swiss air navigation service provider skyguide. Along with access to internal documents, we have been able to gain deep insights into an industry that is rarely accessible to research. We use open, axial and selective coding techniques to analyse the raw data, and relied on the diffusion of innovation model from Rogers (1995) to provide a theoretical framework.

*Contribution to this research*

The contribution of this paper to the overall research project is the empirical motivation of the problem domain (ET) and a first glimpse at the solution domain (boundary objects). This paper complements the theoretical motivation of the problem outlined in Paper B. The case company is undergoing a major ET, caused by the transformation of the European air navigation service industry. The paper highlights the potential of a mutually understood and accepted object for establishing shared understanding among communities of practice as heterogeneous in knowledge, values and interests as air traffic controllers, systems engineers, and business divisions of an air navigation service provider.

### 4.2.2 Paper B

*Citation*

Abraham, R. 2013. "Enterprise Architecture Artifacts as Boundary Objects - A Framework of Properties," in *ECIS 2013 Completed Research*, Utrecht, The Netherlands, Paper 120.

*Synopsis*

A structured literature review is performed to identify a set of eleven boundary object properties. A subsequent focus group adds another property to arrive at the final set of twelve boundary object properties.

*Result*

In total, twelve properties are identified (see Table 4). In the following, a short definition is provided for each property. The final property “Participation” is added by the focus group; otherwise, the order bears no significance.

*Table 4: Boundary object properties (Abraham 2013, p. 6 ff.; Abraham et al. 2013, p. 30 f.)*

| Property | Definition |
|---|---|
| Modularity | Modularity enables communities to attend to specific areas of a boundary object independently from each other, such as attending to individual portions of an ERP system (Pawlowski and Robey 2004; Star 2010). |
| Abstraction | Abstraction serves the interests of all involved communities by providing a common reference point on a high level of abstraction. Local contingencies are eliminated from high-level views to highlight the commonalities (Gasson 2006; Levina and Vaast 2005). |
| Concreteness | Concreteness addresses specific problems relevant to specific communities. Communities are able to specify their concerns and express their knowledge related to the problem at hand. Thus, interpretive flexibility is provided (Carlile 2002; Pawlowski and Robey 2004). |

| Property | Definition |
|---|---|
| Shared syntax | Shared syntax provides a common schema of information elements, so that local use of information objects is uniform across communities (Dodgson et al. 2007; Pawlowski and Robey 2004). |
| Malleability | Malleability entails that boundary objects are jointly transformable to support the detection of dependencies and the negotiation of solutions (Carlile 2004; Doolin and McLeod 2012). |
| Visualization | Visualization entails that boundary objects do not rely on verbal definitions, but possess a graphical or physical representation (e.g., a drawing or a prototype) (Boland and Tenkasi 1995; Henderson 1991). |
| Annotation | Annotation enriches boundary objects with additional information by individual communities in order to provide context for local use (Karsten et al. 2001; Yakura 2002). |
| Versioning | Versioning traces changes to boundary objects, along with their rationale. Additional context is provided by reconstructing the chronological evolution of the boundary object (Karsten et al. 2001; Mark et al. 2007). |
| Accessibility | Accessibility includes informing interested communities about the boundary object using appropriate communication channels and other measures aimed at helping communities to use the boundary object, such as trainings. As a result, the boundary object is easier to access for the involved communities (Boland and Tenkasi 1995; Levina 2005). |
| Up-to-dateness | Up-to-dateness includes timely communication of changes to the involved communities as well as responsibilities and processes for updating the boundary object (Carlile 2002; Karsten et al. 2001). |
| Stability | Stability implies that the structure and underlying information objects of a boundary object remain stable over time. Despite different local uses and annotations, boundary objects provide a stable reference frame: While changes at the periphery are possible, the core of the boundary object remains stable and recognizable (Karsten et al. 2001; Yakura 2002). |
| Participation | Participation means that relevant communities should be involved in the creation and maintenance of the boundary object, and that users should also include top management. |

*Research method*

Leading journals from the IS, organization, and general management fields have been analysed for articles dealing with boundary objects. After forward and backward searches, a set of 26 articles has been scanned (full text) for properties of boundary objects. In a second step, a focus group with nine enterprise architects from German and Swiss enterprises has been conducted in September 2012 in Switzerland. The represented enterprises were mainly active in the financial services or electric utilities industries, and the participants held positions in EA, data architecture, IT architecture, or IT strategy. After being introduced to the boundary object concept briefly, they reported on the properties of boundary objects they had encountered in their own enterprises. The intention of the focus group was thus not to confirm or reject the boundary object properties identified in literature, but to identify properties that had been missed in the previous step.

*Contribution to this research*

The contribution of this paper to the overall research project is the breaking down of the central concept in the solution domain into individual components (i.e., breaking down boundary objects into single properties). This paper complements the empirical motivation of boundary objects in ET from Paper A with a theoretical motivation. It is arguably the central paper of this research, as all following papers build on it, either by developing situational design specifications (Paper C, Paper D), by developing design principles for certain properties (Paper E), or in the evaluation (Paper F).

### 4.2.3 Paper C

*Citation*

Abraham, R., Niemietz, H., de Kinderen, S., and Aier, S. 2013. "Can boundary objects mitigate communication defects in enterprise transformation? Findings from expert interviews," in *Proceedings of the 5th International Workshop on Enterprise Modelling and Information Systems Architectures (EMISA 2013)*, R. Jung and M. Reichert (eds.), St. Gallen, Switzerland, pp. 27-40.

*Synopsis*

We discuss which knowledge boundaries are the root causes of certain communication defects, and which boundary object properties are required for overcoming those knowledge boundaries (by supporting knowledge transfer, knowledge translation, and knowledge transformation processes, respectively). We further discuss in which situations boundary objects alone are no longer sufficient to establish shared understanding, and where enterprise architects are needed as additional boundary spanners.

*Result*

Table 5 shows which boundary object properties are required for crossing which knowledge boundaries (i.e., which capacities are enabled by which boundary object properties).

*Table 5: Boundary object properties and their capacities (based on Abraham et al. (2013, p. 34))*

| Property | Syntactic capacity | Semantic capacity | Pragmatic capacity | (Not supported by interview data) |
|---|---|---|---|---|
| Modularity | | x | | |
| Abstraction/ Concreteness | | x | | |
| Shared syntax | x | | | |
| Malleability | | | | x |
| Visualization | | x | | |
| Annotation | | | | x |
| Versioning | | | | x |
| Accessibility | x | | | |
| Up-to-dateness | | | x | |
| Stability | | x | | |
| Participation | | | x | |

*Research method*

We have conducted a series of semi-structured expert interviews. Each interview lasted between 60 and 90 minutes. The interview partners were mainly enterprise architects (one management consultant was also interviewed) working in the consulting, banking, or insurance industries. All interviews have been recorded, transcribed, and analysed using an open coding scheme.

*Contribution to this research*

The contribution of this paper to the overall research project is the allocation of boundary object properties to one of the three knowledge boundaries. This paper contributes to a situational design specification by describing which boundary object properties are conductive in which situation. Paper E builds on the results of this paper by developing design principles for building boundary objects with a semantic capacity (i.e., boundary objects that possess those properties associated with overcoming a semantic knowledge boundary).

### 4.2.4 Paper D

*Citation*

Abraham, R., Aier, S., and Winter, R. forthcoming. "Crossing the line: overcoming knowledge boundaries in enterprise transformation," accepted for publication in *Business & Information Systems Engineering*.

*Synopsis*

We have conducted a quantitative study (n=111) to investigate the effect of boundary object properties on syntactic, semantic, and pragmatic capacities. Based on results from Paper B and Paper C, we build a research model, which is then tested empirically. Our findings indicate that the more complex a knowledge boundary becomes, the more important becomes the role of human boundary spanners like enterprise architects. Our findings also confirm the relationships between boundary object capacities; namely, that syntactic capacities support semantic capacities, which in turn support pragmatic capacities.

*Result*

We confirm the majority of our hypotheses regarding the impact of boundary object properties on syntactic, semantic, and pragmatic capacities. We also confirm the effects between the capacities (from a syntactic to a semantic, and from a semantic to a pragmatic capacity), and the effects on the shared understanding construct. We also find support for those properties that could not be mapped to a specific capacity in Paper C. The research model results are shown in Figure 3.

*Research method*

We have operationalized our constructs based on existing measurement instruments and on the results from Paper B. We have then tested our model using partial least squares. Our respondents (n=111) are practitioners and researchers in EA. The sample represents enterprises of different sizes and from various industries.

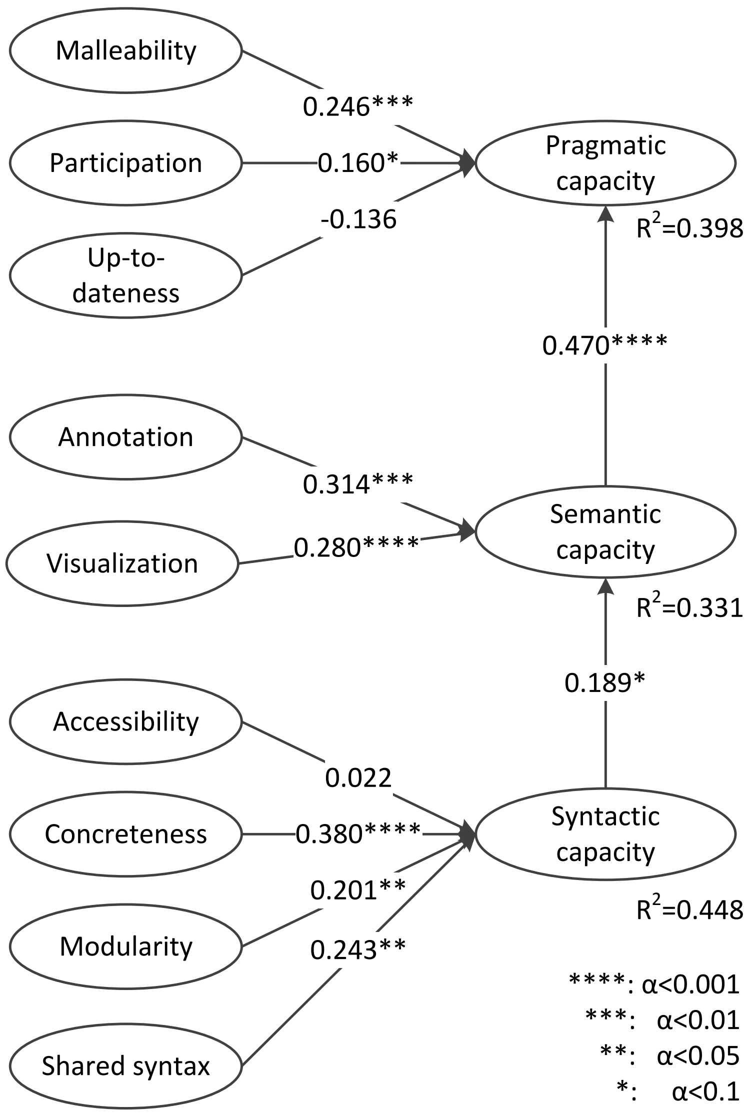


*Figure 3: Research model results (based on Paper D, Figure 9, Table 19)*

*Contribution to this research*

The contribution of this paper to the overall research project is a refinement of the overall research model. First, the distinction between boundary object construction and management properties introduced in Paper C has been dropped in this paper and the following papers (Paper D, Paper E, and Paper F). This decision is motivated by the sociomaterial perspective first introduced in this paper, which advocates to jointly consider an artefact's a social and material aspects.

Second, this paper introduces the concept of in boundary object capacities and positions shared understanding as an antecedent to shared knowledge: after shared understanding has been established at a certain knowledge boundary (syntactic, semantic, pragmatic), knowledge can be transferred, translated, or transformed.

The results of Paper C and this paper are not identical. Paper C associates other boundary object properties to syntactic, semantic, or pragmatic capacities. A potential explanation for this disparity, other than the different research methods used, could be that the interview partners in Paper C were all enterprise architects (except one management consultant), whereas the respondents filling out the questionnaire, although attending EA-focused events, were not necessarily enterprise architects. Another explanation might be that in Paper C, the interview partners reported explicitly on ET projects, whereas in this paper, the respondents reported on model properties in general, but the scenario was not restricted to ET.

### 4.2.5 Paper E

*Citation*

Abraham, R. forthcoming. "Design principles for turning architectural models into boundary objects," accepted for publication in *Architectural Coordination of Enterprise Transformation*, H.A. Proper, R. Winter, S. Aier and S. de Kinderen (eds.), Berlin, Heidelberg, Germany: Springer.

*Synopsis*

Design principles for turning architectural models into boundary objects are derived. This paper focuses on the semantic capacity of boundary objects: a syntactic capacity alone is likely insufficient in ET contexts (and possibly already covered by existing EA models), while for a pragmatic capacity, the role of human boundary spanners like enterprise architects dominates when compared the role of boundary objects. Four boundary object properties are associated with enabling a semantic capacity (see Paper C): visualization, modularity, abstraction/concreteness, and stability.

*Result*

The following four design principles are expressed via the core meta-model for EA design principles (Aier et al. 2011c). In Table 6, the rationale and statement for each design principle are provided.

*Table 6: Boundary object design principles (Paper E, Section E.4)*

| Design principle | Rationale | Statement |
|---|---|---|
| Visualization | Cognitive efficiency is essential for understanding and accepting models. | Design cognitively efficient EA models to improve shared understanding in ET. |
| Modularity | User-based contextualization is more suitable for creating shared understanding than designer-based contextualization. | Provide all information in one view, so that users do the filtering themselves. |
| Abstraction/ concreteness | Depending on the level of cooperation, resp. the degree of conflict, one global or several local models are preferable. | Provide users with the ability to navigate between different levels of problem description. |
| Stability | A stable boundary object is able to gain legitimacy from communities of practice, while a boundary object that is perceived as too volatile tends to be ignored. | Provide a boundary object whose structure remains stable and recognizable across communities of practice. |

*Research method*

An experiment has been conducted to assess which visualization principles from Moody's design theory (Moody 2009) are applicable to the boundary objects and ET context. The subjects were eleven participants pursuing a PhD in the EA field, who were presented with an illustrative ET example. For the other properties, design principles have been derived from literature. Finally, the core meta-model for EA principles of Aier et al. (2011c) has been adapted to express the boundary object design principles.

*Contribution to this research*

The contribution of this paper to the overall research project is the development of the design principles based on the boundary object properties identified in Paper B. The allocation of boundary object properties to boundary object capacities from Paper C has been chosen over the one from Paper D, since Paper C explicitly investigated an ET scenario.

A major limitation of this paper is the focus on the semantic capacity, hence no design principles for boundary object properties associated with syntactic or pragmatic capacities are provided. However, since the purpose of this paper is to provide an example of a design principle development process (showing how design principles can be developed either theoretically or empirically), rather than developing a final set of principles, this limitation and the focus on the results from Paper C seem appropriate.

Furthermore, to provide actionable advice to practitioners, this paper has to shift the level of abstraction regarding the boundary object properties to a more detailed level (as compared to Paper B, Paper C, and Paper D). (1) Visualization is operationalized as a cognitively effective visual notation. (2) Modularity is operationalized as user-based rather than designer-based contextualization (i.e., a preference of unfiltered information over pre-defined viewpoints). (3) The balance between abstraction and concreteness is operationalized via navigation capabilities through different levels of problem description. (4) Stability is operationalized as a defined change management process.

### 4.2.6 Paper F

*Citation*

Abraham, R., Aier, S., and Winter, R. forthcoming. "Fail Early, Fail Often: Towards Coherent Feedback Loops in Design Science Research Evaluation," accepted for publication in *Proceedings of the International Conference on Information Systems (ICIS 2014)*, Auckland, New Zealand.

*Synopsis*

We propose feedback loops to maintain coherence between evaluation activities in DSR projects. To maintain coherence between the problem definition and the final evaluation during real-world use, we suggest explicating the underlying notion of relevance at the outset of the DSR project. To maintain coherence between the design specification and the implementation, we propose to create situation-specific design specifications. Finally, we formulate a research agenda consisting of six avenues for further research. This research agenda is motivated by the different levels of abstraction contained in the evaluation activities and is structured along the different types of generalizability (Lee and Baskerville 2003; 2012).

*Result*

Table 7 summarizes how our proposed feedback loops are applied to this research, shows evaluation activities concerning the design process, and proposes an evaluation strategy for the design product.

*Table 7: Summary of evaluation activities in this research (based on Paper F, Section F.4)*

| Eval activity | After design activity | Application to this research |
|---|---|---|
| Eval 1 | Problem identification | • Notions of relevance aimed at: conceptual, instrumental<br>• Assessment of conceptual relevance: analysis of literature on organizational change and EA, boundary objects as a potential means to achieve desired end (shared understanding) (Paper B)<br>• Assessment of instrumental relevance: case study in air traffic management industry (Paper A) |
| Eval 2 | Design | • Evaluation of solution components via structured literature review and focus group (Paper B)<br>• Evaluation of design specification (boundary object properties) via expert interviews (Paper C)<br>• Ex-ante demonstration of artefact in specific situation by linking boundary object properties to syntactic, semantic, pragmatic capacities (Paper C) |
| Eval 3 | Construction | • Experimental evaluation of visualization design principle (Paper E) |
| Eval 4 | Use | • Not yet performed, proposal of single case study to apply boundary object concept and the effect of the formulated design principles in a real-world setting, covering the "three realities" of real tasks, real systems, and real users (Sun and Kantor 2006) |

*Research method*

We review the existing design science literature to compare evaluation perspectives, and decide to build on the DSR process proposed by Sonnenberg and vom Brocke (2012b). This process suggests an evaluation activity after problem identification, design, construction and use activities, rather than a single evaluation activity at the end of the entire DSR process. We discuss the feedback loops using this research as an example. Finally, we propose a research agenda.

*Contribution to this research*

The contribution of this paper to the overall research project is an overview of the evaluation activities performed during this research, as well as an outline on how to evaluate the design principles in an Eval 4 activity. By outlining such a concept, this paper proposes a mitigation for a major limitation of this research, namely that no evaluation of the artefact in the “three realities” of real tasks, real systems, and real users (Sun and Kantor 2006) has been performed yet. This paper emphasizes the importance of evaluating the design process as well as the design product, and highlights the evaluation activities Eval 1, Eval 2 and Eval 3 performed throughout this research.

## 4.3 Reflections on the design principle construction process

In a DSR project, emphasis must be placed on the artefact construction process, as well as on the artefact itself. Without a rigorously defined and evaluated construction process (i.e., working in an intuitive, ad-hoc way), resources might be wasted, the construction process cannot be re-used to efficiently create a similar artefact, nor can rigorously developed insights be contributed to the DSR knowledge base (Gregor and Jones 2007; Gregor and Hevner 2013).

Therefore, this research emphasizes not only the set of design principles, but to an equal degree the process of their construction. A rigorous design process has been followed by first identifying the generalized solution components in Paper B (the boundary object properties), and then investigating which boundary object capacities they enable (Paper C). The results at this stage are essential input for constructing the actual design principles.

Paper E shows exemplarily how design principles for properties that enable a semantic capacity can be constructed. Given that construction and evaluation activities in DSR should be closely intertwined (Sonnenberg and vom Brocke 2012b), similar methods (e.g., interviews, experiments) may be used for both types of activities. Methods to construct design principles in this research include synthesizing academic and practitioner literature as well as experiments (e.g., the experiment on visualization principles reported in Paper E).

The selection of the appropriate construction method should be subject to both epistemological and economic considerations. While empirically constructed design principles already contain an evaluation component and can be deemed fit for the intended field of application (assuming that the empirical methods have been applied rigorously), theoretically derived design principles do not contain an evaluation component. Applicability for the specific problem context has to be shown otherwise, for example empirically or via causal analysis (Gregor et al. 2013). An example would be reflecting how certain material properties of the artefact entail certain outcomes in a specific setting ("passive causal analysis" (Gregor et al. 2013, p. 10)).

In this research, the visualization design principle has been constructed empirically, while the abstraction/concreteness, modularity and stability design principles have been derived via causal analysis. For the latter design principles, design insights have been extracted from previous studies that link material properties of an artefact (e.g., whether one global or multiple local models were used) with meeting specific ends in a specific setting (e.g., improved information processing via global models, conflict resolution capabilities of local models, or preferences of use-based over designer-based contextualization (i.e., viewpoints)). The applicability of these insights in the context of the newly constructed design principles (i.e., applying the design principle for modularity in ET) is then shown via an "informed argument" (Hevner et al. 2004, p. 86) in Paper E, by arguing for the transferability of the results from existing literature to ET, and thereby for the applicability of the newly designed design principles in an ET context.

Economically, conducting empirical work carries a significant penalty due to the high effort involved. Designers must therefore balance epistemological and economic considerations while constructing their design principles, and should resort to field research only when design principles cannot be constructed in less costly ways (e.g., when no appropriate knowledge can be found in the DSR knowledge base).

# 5 Summary

## 5.1 Discussion and limitations

This research aims to support enterprises in establishing shared understanding during ET via boundary objects. The problem domain of ET, and the solution domain of boundary objects are motivated empirically in Paper A, and theoretically in Paper B. After a set of boundary object properties has been compiled in Paper B, these properties are mapped to overcoming syntactic, semantic, and pragmatic knowledge boundaries in Paper C using a qualitative research method. Thus, a situational design specification is created—which boundary object properties are required in which situation?

Paper D also aims at producing a situational design specification, but takes a quantitative rather than a qualitative approach. Some adjustments are made to the research model. First, boundary object properties are now conceptualized as enabling a respective syntactic, semantic, or pragmatic capacity. This capacity may then contribute to shared understanding at the respective knowledge boundary—either by itself in the event of a syntactic knowledge boundary, or with the support of a boundary spanner like an enterprise architect in the event of a semantic or pragmatic knowledge boundary. Second, a sociomaterial perspective has been introduced in Paper D as a theoretical lens to inform further research. In accordance with the idea of regarding social and material aspects of artefacts simultaneously, the division of boundary object properties in constructional and management properties from Paper C has been dropped.

Paper E exemplarily develops design principles for those boundary object properties associated with a semantic capacity. For this purpose, a shift regarding the level of abstraction is performed: while the boundary object properties are on a high level of abstraction as results from a literature review in Paper B, or constructs in a structural equation model in Paper D, a much lower level of abstraction is needed in Paper E to arrive at implementable design principles.

Finally, the evaluation aspects contained in all papers are summarized in Paper F, using an established cycle that places an evaluation activity after each design activity (Sonnenberg and vom Brocke 2012b) and thereby contributes equally to evaluating the design process and the eventual design product.

This research contributes in three ways. First, a set of twelve boundary object properties has been identified. Second, these properties have been linked to syntactic, semantic, and pragmatic capacities of boundary objects. Third, design principles have been formulated for implementing selected boundary object properties.

By introducing the concept of boundary objects in ET situations, conceptual relevance is achieved. Introducing a specific linguistic construct for a specific type of model (i.e., one that serves as a boundary object), this research uncovers requirements for models that may help practitioners to understand why a given object does or does not help them to establish shared understanding. How shared understanding can be established is further dependent on the specific situation. The presence of knowledge boundaries has been identified as one particular important factor in explaining which boundary object properties work at syntactic, semantic, or pragmatic knowledge boundaries. This distinction helps practitioners to better understand cause-effect relationships between boundary objects among specific communities of practice and the establishment of shared understanding. Finally, exemplary design principles for four selected properties (abstraction/concreteness, modularity, stability, and visualization) have been developed. By applying these principles to existing models, or considering them during model generation processes (e.g., when a to-be model is generated during the ET planning process), this research provides actionable advice for practitioners and thus also approaches instrumental relevance. Summarizing, all RQs have been answered by identifying boundary object properties, discussing their applicability in specific situations, and formulating design principles for implementing selected properties in architectural models.

Yet, no research is without limitations, and this research is no exception. Some of the limitations inherent in this research deserve particular emphasis, as they lead to new research opportunities. First, this is a cumulative research project where later papers build on results from earlier papers. Despite the evaluation efforts described in each paper, and summarized in Paper F, flaws at any stage in this research might affect the validity of subsequent results. This limitation is exacerbated by long-running, cumulative research efforts (Pries-Heje et al. 2008), underlining the importance of early and frequent evaluation activities to mitigate the effects as far as possible. For example, the importance of establishing shared understanding in ET could be overrated, despite a plethora of literature and practical case experience (as reported in Paper A) indicating otherwise. Important boundary object properties could have been missed in Paper B (e.g., due to inadequate search terms or flaws in the coding process). The mapping of the property set to syntactic, semantic, or pragmatic capacities in Paper C and Paper D could be flawed, or the design principle construction process in Paper E might not be suitable. In particular, the mapping of the property set to syntactic, semantic, and pragmatic capacities differs between Paper C and Paper D, which may be caused by differences in research method, informants, and scenario (qualitative vs quantitative, enterprise architects vs other communities of practice, and ET vs modelling in general). This mapping should thus be subject to further research efforts.

Second, not all identified boundary object properties have been translated into design principles. Instead, this research has concentrated on formulating design principles that enable a semantic capacity. After all, principles should be “few in number” (The Open Group 2011, p. 237). The rationale behind the principle definition is to provide advice to practitioners that can be implemented rapidly in ET projects, rather than striving for perfect principles at the expense of timeliness and complexity. Thus, practitioners may quickly engineer and apply 80 percent of a boundary object, and let the other 20 percent to emerge during application (e.g., properties like accessibility or participation). The limitation of the design principles in number thus adheres to the Pareto principle or “80-20 rule” (Reed 2001).

Third, not all design principles have been validated empirically. Still, an experiment has been conducted for the visualization property, and evidence from literature is provided to support the other design principles. Moreover, this research has demonstrated the feasibility and effectiveness of the design principle construction process, so that principles for other properties can be constructed in analogy to the existing ones.

Fourth, the effectiveness of a boundary object may be influenced by contingency factors other than the presence of knowledge boundaries. For example, power relationships among the involved communities of practice and their hidden/political agendas are play an important role in deciding whether or not a boundary object will be successful (Barley et al. 2012; Oswick and Robertson 2009). Nevertheless, as stated at the outset of this research, the contingency factor of knowledge boundaries is assumed to provide a sufficient level of abstraction to capture the diversity of different organizational communities (communities that go by different names in different enterprises, but whose difficulties in establishing shared understanding can be traced back to the presence of one of the three knowledge boundaries).

Finally, no real-world evaluation has been performed. Since the artefact is intended to be applied in a complex and long-running context, effects can only be observed with considerable delay. Hence, the effect of boundary objects in establishing shared understanding would ideally have to be observed over the entire duration of an ET (i.e., over two to five years). Gaining access to industry partners and the resources required to conduct such an evaluation in the “three realities” of real tasks, real systems, and real users (Sun and Kantor 2006, p. 614) is a tremendous challenge for any DSR project. Nevertheless, by clearly stating this limitation, and by following a rigorous artefact construction process, important groundwork has been laid. By formulating four design principles, this research provides a first means for the purposeful design of boundary objects in ET. To assess the impact of other, time-dependent properties like accessibility and participation that unfold during use, a long-term observation could be conducted in further research.

## 5.2 Implications for theory

With the boundary object concept, a solution that has been frequently applied and tested in domains such as product development or software development is transferred (“exaptation” (Gregor and Hevner 2013)) to the new domain of ET. Thereby, this research contributes to the boundary object concept by enlarging its scope of applicability.

Looking at the fruitfulness for further research (Aier and Fischer 2011), the effect of the design principles developed in this research might be observed in an actual ET project. As a framework for analysis on the effectiveness of these design principles, the sociomaterial perspective appears particularly promising from a research point of view. The ontological compatibility between boundary objects and sociomateriality has already been established in prior research (Doolin and McLeod 2012). Observing the evolution, manipulation, and application of boundary objects in an ET context from a sociomaterial perspective may contribute to research in ET, sociomateriality, and IS in general.

First, a longitudinal study of boundary objects in ET could yield insights into how certain boundary objects shape the course of ET, and vice versa. The design principles could be directly used here as a means for manipulating boundary objects and observing the resulting effects.

Second, ET as a context that is characterized by high environmental uncertainty, diversity and rivalry among the involved communities of practice, can yield important insights into basic aspects of sociomateriality. For example, the role of temporal emergence, the importance of practice, or the process of simultaneously describing and creating reality (performativity) (Doolin and McLeod 2012) could be observed in a longitudinal study over the course of an entire ET project. Also, researching boundary objects in ET from a sociomaterial perspective could show that the abstract perspective of sociomateriality is applicable in a specific context like ET.

Third, such research would contribute to IS research in general by restoring a fair balance of the social and the material. Currently, there is a perceived bias towards the social in IS research (Benbasat and Zmud 2003; Orlikowski and Iacono 2001), and there are claims for the IS community to "provide significant contributions by drawing on the sociomaterial perspective, which has emerged as a robust intellectual tradition of the IS community, and by attending explicitly to the generative materiality of digital artifacts" (Yoo 2013, p. 232).

## 5.3 Implications for practice

For practitioners, the set of boundary object properties, the mapping of these properties to syntactic, semantic, and pragmatic capacities and the proposed design principles can help to understand why some models work as boundary objects in an ET context, and why others do not. Designated boundary spanners (e.g., enterprise architects) may use the results of this research to improve their understanding of cause-effect relationships of the effectiveness of certain models in establishing shared understanding among certain communities of practice (conceptual relevance). They may also use and implement the proposed design principles as very practical advice for improving their existing or creating new models (instrumental relevance). Finally, boundary spanners are often challenged for missing legitimacy in either of the communities that they belong to (Abraham et al. 2013; Levina and Vaast 2005). By being able to point out and explain boundary objects to different communities of practice, boundary spanners may also be able to respond to these challenges and gain trust and reputation (legitimative relevance).

# Part B: Papers of the dissertation

## Paper A – Why Innovation In Air Navigation Services Is So Difficult In Europe? - A Study Identifying Current Obstacles And Potential ICT Enablers

*Table 8: Bibliographical metadata on Paper A*

| Attribute | Value |
|---|---|
| Title | Why Innovation In Air Navigation Services Is So Difficult In Europe? - A Study Identifying Current Obstacles And Potential ICT Enablers |
| Author(s) | Breitenmoser, Pablo[1]; Abraham, Ralf[2]; Eurich, Markus[1]; Mettler, Tobias[2]<br>[1]ETH Zurich, Scheuchzerstrasse 7, 8092 Zurich, Switzerland<br>[2]University of St. Gallen, Müller-Friedberg-Strasse 8, 9000 St. Gallen, Switzerland<br>pbreitenmoser@ethz.ch, ralf.abraham@unisg.ch, meurich@ethz.ch, tobias.mettler@unisg.ch |
| Selected approach for order of authors | Sequence determines credit |
| Publication outlet | ECIS 2013 Completed Research |
| Publication type | Conference paper |
| Publication year | 2013 |
| Rating (Jourqual 2.1) | B |
| Publication status | Published |

*Abstract*

The Air Navigation Service (ANS) industry has not experienced many major technological innovations in the last decades. Despite its indisputable contribution to economic welfare, it relies on Information and Communication Technologies (ICT) that lag way behind their current technological potential. Yet, it is not well understood what exactly restrains ANS providers from introducing novel ICT systems despite the legacy ICT in use which reaches the end of its life-cycle. On the basis of an interview series with managers in the ANS industry, this study sheds light on the various barriers that hinder the diffusion of technological innovation. Our findings suggest that the stagnation in technological innovation cannot be ascribed to one single obstacle, but rather to intertwining political, economic, social and technological aspects. This study concludes by proposing ICT approaches to tackle the identified barriers. The analysis of obstacles and potential ICT enablers can support decision makers of ANS providers and can enable business transformations in the ANS industry. ICT researchers can use this study as a help for developing ANS technologies, and business researchers can focus on specific incentives to foster innovation.

*Keywords*

Air Navigation Services, Business Model, Diffusion of Innovation, Innovation, Management, Technology-driven Business Transformation

## A.1 Introduction

It may be unsettling to realize that while several airlines have recently launched in-flight Wi-Fi internet for their passengers, their pilots still communicate by analogue radio with ground staff. The discrepancy between passenger entertainment services and air navigation services (ANS) has one minor and one major reason. The minor reason is the reaction of the airlines to the sudden wide-spread use of smart phones and tablets: by offering wireless internet, they hope to gain more passengers based on the introduction of the new technology. The major reason is that technological innovation in ANS has been stagnating for decades. This stagnation is pushing the current information and communication technology (ICT) systems to its limits. The forecasts of the European air traffic management organisation Eurocontrol predict an annual growth rate of flight movements in Europe of 2.6 per cent until 2030, i.e. flight movements are assumed to double by 2036 (SESAR Joint Undertaking 2012).

To deal with the projected increase in traffic, the ANS information systems will have to undergo technological improvements (SESAR Joint Undertaking 2012, p. 30). The ICT in use restricts the amount of aircraft that can be served with ANS: the capacity limits have been reached, especially around busy airports (London, Zurich, etc.). The resulting queues inevitably lead to delays, additional environmental pollution and higher costs (European Commission 2012).

In the light of such ICT limitations and the increasing demand for ANS, there is a strong need to transform the industry towards more adequate ANS provision. Since ANS is crucial to sustaining the economic welfare in Europe, air navigation service providers (ANSP), airlines, airports, and governmental, organizational and legislative bodies have started to discuss this problematic situation, but progress is slow. Yet, it is not well understood what exactly restrains ANS providers from introducing novel ICT systems. It is also not clear which ICT transformations would be able to foster effective innovation in the European ANS industry.

The goal of the study is to reveal obstacles that make innovation in ANS so difficult and to contribute to the understanding of the technology diffusion process in the ANS industry. We applied an empirical approach by conducting an interview series with representatives of the Swiss ANSP skyguide to identify innovation obstacles in ANS. On the basis of the identified obstacles, we propose ICT-based techniques to overcome some of these barriers. This techniques can contribute to actively push for changes of in the perception and behaviour of stakeholders with the goal to pave the way for enterprise transformations.

Organizations in the ANS industry are prime examples for High Reliability Organizations (HRO) – organizations, for which failures could have catastrophic consequences. In HROs, failures (e.g., plane crashes) affect multiple innocent bystanders and receive high media coverage. Therefore, safety is a paramount objective that is pursued via a systemic approach. HROs are constantly searching for ways to improve their safety. Before a (technological) change can be introduced to an HRO, it must pass comprehensive tests to ensure that it does not negatively affect system safety, availability and reliability. There are few, if any, studies that investigate enterprise transformation in HRO. This study is one of the first of its kind to address this challenge in an HRO and particularly in the ANS industry. Up to now, there is hardly any related work , because the ANS industry does seldom grant access to researchers.

## A.2 Innovation in the Air Navigation Services Industry

The European Commission (EC) launched the Single European Sky (SES) initiative to handle the projected increase of flight movements. The SES ATM Research (SESAR) programme was launched as part of SES with the goal to develop a new generation of ANS that will be able to ensure the safety and fluidity of air transport in Europe and subsequently on a global scale.

The fragmentation of the European airspace has been identified as a major obstacle to achieve these goals. The formation of Functional Airspace Blocks (FAB) is planned to tackle this issue. FABs will lead to a different type of sectorisation: the airspace will be divided according to traffic flows and no longer according to national borders. Since a single FAB covers several countries, individual ANSPs (which are affiliated to a country) will have to collaborate more closely than they did in the past. This creates a high demand for interoperability between all the different ICT components and ANSP architectures that are now in use. Today's ANSP are monolithically integrated – both in their organizational as well as in their technological systems architecture – due to the slow development during the last decades.

Progress in implementing this transformation has been slower than expected. Besides technological obstacles, transformation in this industry is also hampered by political barriers like the fear of uncontrolled airspace infringements and the loss of national sovereignty; economic barriers, like the lack of liquidity for investments; and social barriers, like the loss of power of the unionized air traffic controllers (ATCO). In addition, the liberalization of the industry has led to different legal forms under which the ANSP of today operate. The legal form can range from traditional state ownership, through a variety of corporatized structures, to regulated private companies. Although legal setups have partially changed, the liberalization has not led to more innovation.

ANS industry studies about enterprise transformation are usually looked at on a case-by-case perspective. Case study evidence is organized as an intellectual capital portfolio and links are drawn to business outcomes for other organisations.

Scholars who have studied the impact of transformation, such as Button and McDougall (2006), assess the implications of the ANSP structure in correspondence with managerial approaches. Lewis and Zollin (2004) use management boards as a proxy for the correlation between the type of company (public vs. private) and its performance. Arvidsson et al. (2006) conducted a study, in which they determine the organizational climate with respect to transformation and innovation in order to investigate the organization's capacity to cope with transformation. These case studies contribute to understanding ANSP management in the light of "transformation", but do not provide information about barriers.

From a technological perspective, innovation in the ANS industry has a strong focus on optimizing Man-Machine Interaction, i.e. air navigation systems that heavily rely on human involvement. In the following, we identify the major subsystems and whether there are industry standards available for the information objects they process:

(1) Flight Data Processing (FDP): FDP processes flight plan data and is the biggest subsystem of the ANSP infrastructure. A flight plan is a standardized document that contains information such as aircraft origin, destination and planned trajectory (Icao 2001). The flight plans are filed before departure, but may be changed during the flight by an ANSP (e.g., to circumnavigate hazardous weather conditions). There is no defined common standard, yet development efforts of the SESAR program are underway towards a Flight Object Interoperability Specification (ED-133).

(2) Radar Data Processing (RDP): This system processes incoming radar data from several sources (which indicate an aircraft's altitude and speed) and presents the information to the air traffic controllers (Eurocontrol 1997). With ASTERIX (All Purpose Structured Eurocontrol SuRveillance Information EXchange), a standard is available.

(3) Environmental Data Processing (EDP): This system processes environmental data such as meteorological data to ATCOs. With the Aeronautical Information Exchange Model, a standard is available.

(4) Communication (COM): This system provides air-to-ground (Pilot to ATCO) and ground-to-ground (ATCO to ATCO) communication capabilities. Communication may either be performed between humans (voice link), or between systems (data link). Standards for both communication types are available from the International Civil Aviation Organization (ICAO).

## A.3 Transformational Perspective on ANSP Industry Innovation

In order to achieve a sustainable transformation of the ANS industry, there is a need, both to transform the ANS service provision and to address the needs of the single ANSP so that it can provide its service in the intertwined industry. The decision of whether to adopt or reject new IT architecture components is fundamental to ANSP enterprise transformation and the transformation of the industry. There are obstacles which hamper this process and which, to a certain degree, impede innovation and its diffusion.

For the sake of revealing obstacles to the introduction of innovations, we refer to the technology diffusion model of Rogers (1995) as an explanatory model. Given the lack properly publicly documented technological innovations in the ANS industry (SESAR Joint Undertaking 2012), the model of Rogers provides an appropriate framework: It highlights the diffusion process of technological innovations, while also taking the effects of social factors into account; in this way, it does not represent a solely technocratic view. The technology diffusion model describes innovation diffusion by dividing the process into four specific stages (Figure 4).

i. The knowledge stage defines the phase of learning of the existence of a certain new technology. This knowledge motivates an individual or an organization to learn more about how the innovation can be used in its environment. Finally, one's knowledge of the technology is to be extended in order to gain an understanding of how and why it works.

ii. The persuasion stage is characterized by exploiting the information of the technology. It is an emotional phase, in which people and organizations conceive an opinion on an innovation. In this stage the involved party considers using the technology within its particular environment.

iii. The decision stage is the point where a technology is either adapted or rejected. This decision is based on the analysis of the potential political, economic, social and technological consequences of the innovation.

iv. The confirmation stage is the phase in which habits and practices change due to the adoption of the technology. Reinvention also occurs during this stage, with the goal of improving overall compatibility (Rogers 1995).

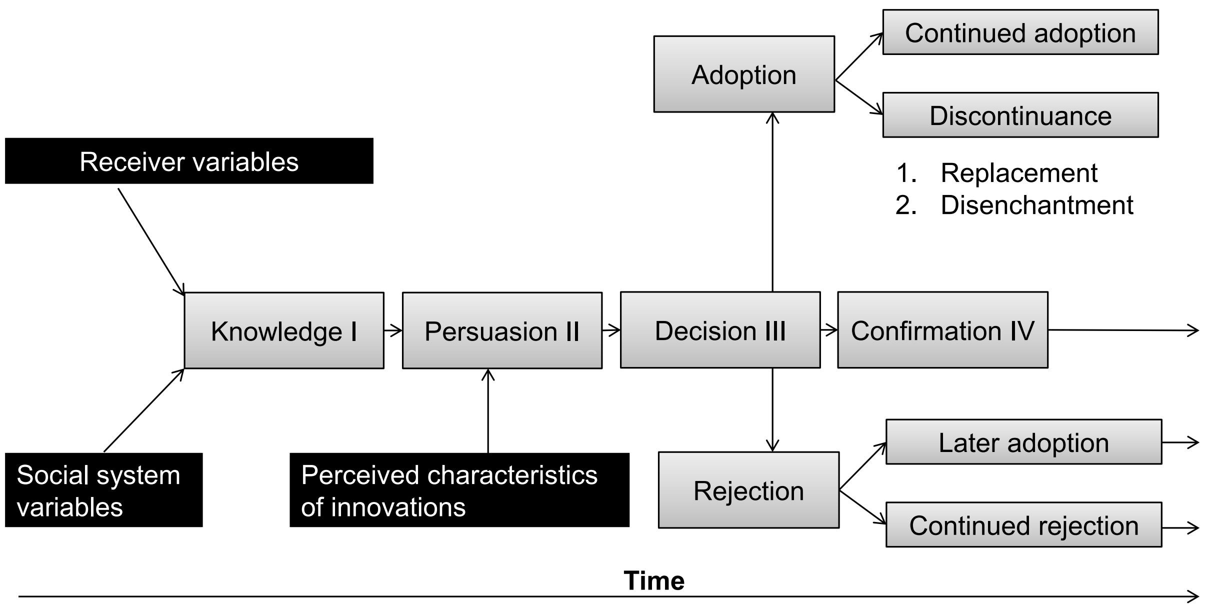


*Figure 4: Simplified Technology Diffusion Model (Rogers 1995)*

## A.4 Method

Not much related work has been done so far since the industry does not regularly provide access to researchers. The goal of this study is not only to understand the obstacles towards technology innovation that ANS enterprises face, but also to actively influence the perception and behaviour of stakeholders in the long run. Therefore, the study is based on a pragmatic epistemological approach, which is aiming for constructive knowledge that can be applied usefully in action (e.g., Goldkuhl 2012; Goles and Hirschheim 2000; Wicks and Freeman 1998). The essence of pragmatic qualitative research lies in the interplay between actions and intervention: in order to alter certain aspects of reality, actions are required (Blumer 1969) Knowledge (e.g., natural laws, social norms, empirical evidence) is essential to change reality into a desired end-state. In this sense, actions and their impact can also contribute to further cognitive clarification and development (Goldkuhl 2012). This is in contrast to, for instance, positivist research which exclusively seeks to explain reality by using models (or a structure of relations) and which uses methods that emphasise the discovery of new knowledge and verify existing (structural) knowledge without actively distorting reality (Denzin and Lincoln 2000).

As a first step in a larger research endeavour, we started our inquiry by getting a deeper understanding of the cognitive beliefs, perceptions, and plans of senior management and other personnel responsible for innovation and technology management at Skyguide, which is the ANSP of Switzerland. Skyguide has about 1,400 employees, including more than 540 civil and military air traffic controllers. Over 300 engineers, technicians and IT-experts are responsible for the development and maintenance of the complex technical installations and facilities. The operators of aeronautical data manage information to assure smooth air traffic.

Data was gathered by means of semi-structured interviews. In total, eight managers were interviewed which result in 30 interview hours (Table 9). Each interview began by asking broad questions about the status quo of the ANS industry, followed by asking more specific questions about the future development of the industry and the role of ICT to enable and support this change. A combination of focussed and open-ended questions was used. The latter were asked in order to ensure that a comprehensive understanding was attained. In doing so, we adhered to the approach advocated by Bouchard (Bouchard 1976), who explicitly calls for re-focussing during an interview. This provides a greater flexibility than completely structured interviews. To prepare for the interviews, we analysed a multitude of technical reports, internal presentations, project documents, annual reports, and press releases (Table 9).

*Table 9: Interview series (note: h = hour)*

| Interviewee | Main topics discussed | Documents analysed |
|---|---|---|
| Chief executive officer (3h) | Vision and business model of future ANS industry | Annual report, internal presentations, press releases |
| Chief operations officer (2h) | Vision of future ANS industry and organizational change | Third-party commissioned technical report (European air traffic management master plan) |
| Chief information officer (4.5h) | Requirements engineering process and IT architecture | Third-party commissioned technical report (standardization in ANS-industry) |
| Head of change management (2h) | Innovation process and organizational change | Internal presentations |
| Head of safety, security, and quality (2.5h) | Perceived changes and future requirements for safe air traffic control | Third-party commissioned technical report (impact of SESAR) |
| Head of engineering and technical services (2h) | Innovation process and implementation roadmap | Third-party commissioned technical report (feasibility study for European air navigation services) |
| Project manager (8h) | Project goals, implementation roadmap, organizational change | Project documentation, internal presentations |
| External consultant (4h) | Industry Transformation requirements and Value Chain Impacts | Virtual Centre Business model, internal presentations |
| Chief executive officer (Skysoft) (2h) | Standardized Human Machine Interface (HMI) and service delivery for future ANSP | Project documentation, internal presentations |

Data obtained was first analysed using open, axial and selective coding techniques (Urquhart 2001). The extracted main statements and assertions were then grouped using STEP / PEST analysis (Political, Economic, Social, Technological) as a mental model (e.g., Mettler and Eurich (2011)) to determine specific areas for future interventions. In order to add to our findings, we led a focus group discussion involving key actors concerned with driving enterprise transformation and technological innovation at Skyguide. This included verifying the statements from the semi-structured interviews and the allocation of obstacles with the key actors in view of completeness and applicability for future work.

## A.5 Findings

To group the statements and assertions, we use the concept of PEST / STEP as an analysis framework of macro-environmental factors. Peng and Nunes (2007) proposes the use of PEST analysis as a tool to identify narrower contexts and focus research questions around feasible and meaningful regional contexts. According to Mettler and Eurich (2011), STEP can be used as a mental model for determining specific areas of future interventions. We found a total of 11 obstacles to enterprise transformation in the ANS Industry: Three political, three economic, two social and three technological obstacles that could be assigned to the knowledge phase and the persuasion phase.

In Figure 5, we map the identified obstacles to the technology diffusion model of Rogers (1995).

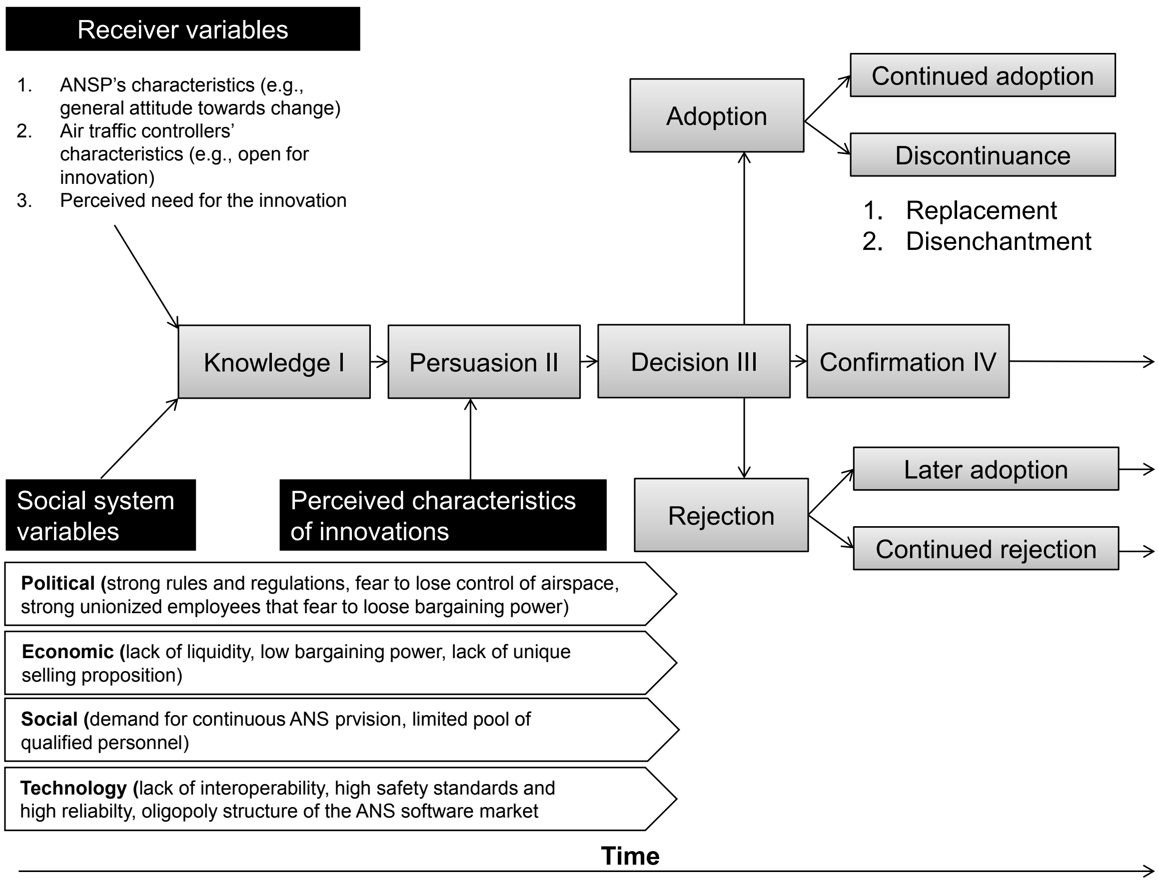


*Figure 5: Technology Diffusion Model adapted to the ANSP Enterprise Transformation on the basis of Rogers (1995)*

The study revealed that in all parts of STEP, the diffusion of innovation is bristled with obstacles to overcome. The mental states of the stakeholders that are described in the model of Rogers (1995) are generally influenced by one or several dimensions of STEP.

*Politically*, regulators need to understand how and why a technology works to build trust in the innovation and to get able to deal with changes in regulations (see section 5.1).

*Economically*, ANSP need to learn and understand what it means to operate under competitive conditions. Employees and management face change in the current mode of financing and purchasing (see section 5.2).

*Socially*, the creation of an idea how one could innovate under the highest expectation (safety) for continuous service provision while facing a limited pool of personnel is supposed to be aligned with political, economic and technological obstacles (see section 5.3).

*Technologically*, the study places the most emphasis on showing that ANS can be innovated to significantly increase capacity (see section 5.4) while maintaining or even exceeding current system reliability and safety levels.

### A.5.1 Political obstacles to innovation

*First, the strong rules and regulations:* Historically, the ANSP are predominantly differentiated from one another according to national borders. Since this is the case for most ANSPs within Europe, they are regulated by both international and national rules and regulations. The obstacles are twofold. First, the rules and regulations in ANSP are complex. Being able to understand all the interrelated consequences an enterprise transformation could bring along is time consuming and would require a huge amount of domain knowledge in financial, political, as well as technological aspects. Second, the regulations include an explicit mission of an ANSP, which typically does not mention innovation.

*Second, the fear of governments to lose control over their airspaces:* Keeping sovereignty of its own airspace is historically a strategic political issue of highest interest. The government has the responsibility of dealing with airspace infringement. This is codified by the ICAO legal framework, which holds national states ultimately responsible for offering ANS services over their respective territory. Two questions will have to be answered before any nation would enter a discussion about its sovereignty: First, how will airspace control within a new functional airspace look like and second, what needs to be regulated if airspace sovereignty is not related to national borders. As the CIO remarked: "There are no big bang changes in our industry".

*Third, the strong unionized employees fear losing bargaining power:* Operating procedures are highly formalized and firmly anchored into ATCO. These factors put employees and unions in a very powerful position. Thus, ANSP unions are particularly interested in maintaining the status quo, which provides its members with safe jobs and a strong negotiating position with employers. Salaries of ATCO are very high compared to local average salaries. Therefore, enterprise transformation is regarded very sceptically and the fear of job loss and the loss of privileges, such as early retirement is present.

### A.5.2 Economic obstacles to innovation

*First, the lack of liquidity:* ANSPs are often not-for-profit organizations (due to national regulations). Therefore, ANSPs operate close to the break-even point, with low profits. ANSPs are neither allowed to retain cash for future investments nor do they have access to the capital market for financing purposes. Therefore, ANSPs constantly lack liquidity for innovation and enterprise transformation. Investment for enterprise transformation must come from outside the industry and according to the present regulations, it can only come from governments.

*Second, the low bargaining power of ANSPs:* There are only few suppliers which dominate the market. Against the background of high investment and education costs, an ANSP will not purchase its infrastructure from another supplier once it has chosen its technology and its vendor: The ANSP is at the mercy of the decisions of its provider while the provider has little incentive to innovate. However, our informants are well aware of the dependency of their company from the big vendors, and they would like to see the situation changing. A project manager expressed this concern: "We want to buy components instead of systems". Currently, legislative bodies foster efforts to increase interoperability between systems from different technology vendors. Given the long system life cycles in the ANS industry, our informants expect the impact from these efforts to materialize only after considerable time.

*Third, the lack of a unique selling proposition:* An ANSP operates as a “connector and consolidator of information” with almost no unique selling proposition compared to other ANSPs. Currently, ANSs are almost interchangeable from the service perspective. In case of market liberalization, ANSPs will face difficulties in differentiating themselves from each other, which is likely to result in a reduction of ANSPs within a FAB.

### A.5.3 Social obstacles to innovation

*First, the high demand for continuous ANS supply*: The need for continuous ANS provision leads to high pressure on ANSP management to ensure service supply with a very high reliability. Entire economies are affected when air traffic is interrupted, e.g. due to strikes. Service interruptions gain immediate and intense media coverage and are highly visible to the general public. Therefore, enterprise transformation can only take place if absolutely no negative effect to the continuous ANS supply can be guaranteed.

*Second, the limited pool of qualified personnel*: Applicants are either put off by unfavourable working conditions, e.g., shift duties on nights and weekends or they do not pass the recruiting tests due to the high cognitive demands: figures from Eurocontrol indicate a passing rate of around 6 per cent, not including medical conditions that may further reduce the candidate pool. Air traffic controllers cannot be easily recruited either, as they generally require a minimum of 2.5 years training. This makes it typically difficult for managers to take out ATCOs for strategic projects such as enterprise transformation.

### A.5.4 Technological obstacles to innovation

*First, the lack of interoperability:* Every ANSP has its own monolithic infrastructure. To a large extent, this can be attributed to highly localized data provision which results in a limited data exchange. Currently, ANSPs in Europe run monolithic systems that integrate local data provision (e.g., meteorological, flight plan and surveillance/radar data) with ANS functionalities (e.g., conflict detection or flight trajectory planning). This results in tightly coupled systems at each ANSP which have very limited capabilities for automated data interchange. Existing systems have not been designed for interoperability and for taking advantage of modern communication infrastructure. This lack of interoperability reduces the area of enterprise transformation to the internal structure. As the CEO put it: "The passengers aboard an airplane see some data, for example time-to-destination, on their in-flight screens sooner than we do"

*Second, high safety standards and high reliability:* Modifications have to be thoroughly tested before implementation in order to meet safety requirements. They must be designed for backward-compatibility and integration into existing ICT. Therefore, enterprise transformation is an incremental and time consuming process.

*Third, the oligopoly structure of the ANS software market*: Since integrated systems demand a great deal of industry know-how, the market is shared between few highly specialised enterprises. Entrance barriers for new vendors are high due to heavy investment (and certification) cost. As one of our informants pointed out, the oligopoly structure is compounded by the fact that ANS is a niche market. Therefore, enterprise transformation does not stem from technology providers.

## A.6 ICT approach to enable transformation in the ANS Industry

Although we stress that the technological implications must be seen in the overall industry context with all of its political, economic and social factors, based on our interviews, we pursue a technological approach to describing the barriers that need to be overcome or the obstacles that need to be avoided for enterprise transformation. Technology enablers help create the "knowledge" according to the diffusion model (Rogers 1995), which represents the knowledge about an innovation in its earliest days and creates motivation to learn more about it. It seems that technology is the biggest driver of change in the field.

In order to gain interoperability between ANSPs, establishing a federated data provision layer where all connected ANSPs act as both data producers and data consumers is recommendable. Currently, data between ANSPs are exchanged primarily by voice communication (radio) and paper progress strips (physical paper strips that are printed out at each ANSP whenever an aircraft enters its airspace in order to track the aircraft). With centralized data provision, data available to one ANSP – e.g., the position and travel parameters of an aircraft such as speed and altitude – would become available system-wide immediately, instead of the time-delays as with the current architecture. The current, sequential data exchange model (Figure 6 (a)) with a cloud-based, centralized data exchange model as proposed by the System Wide Information Management (SWIM) concept (SESAR Joint Undertaking 2011) (Figure 6 (b)).

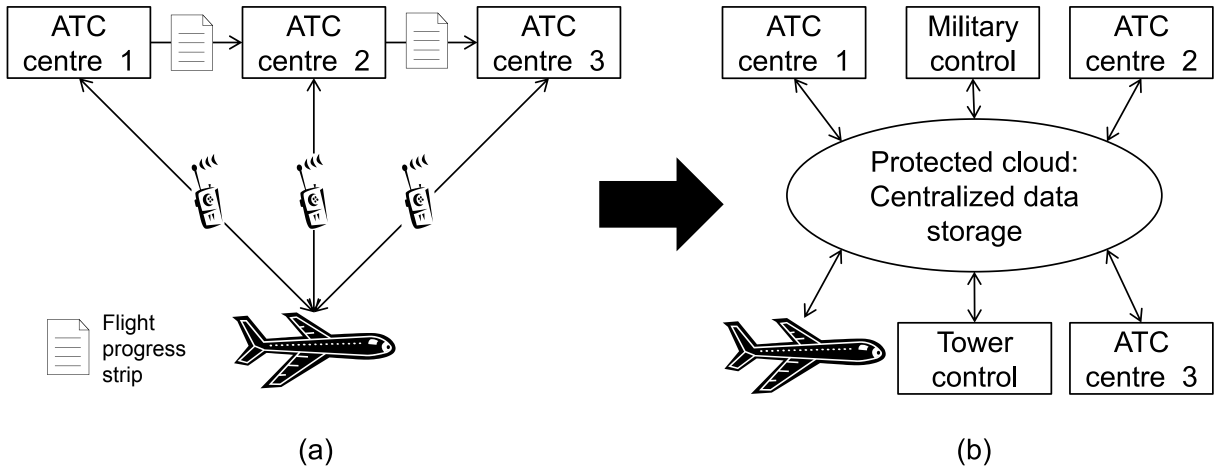


*Figure 6: Sequential versus centralized data exchange*

SWIM implements the following principles: (1) Chronological decoupling of data provision from data consumption: As soon as data is available to any participant, it is fed into the protected cloud, where possible consumers can access it at any time later. All participants act as both data producers and data consumers. (2) Loose coupling between participants: Each participant feeds and receives data via predefined and publicly available standards (see section 2 for the standards defined for the data processing subsystems). (3) A common information model is used to enable data exchange and service definitions.

With standardization, electronic data interchange between aircrafts and different ANSP can be increased instead of relying on transmitting information via voice communication. This eventually paves the way for increasing automation and finally freeing capacity: For example, applying conflict detection components (support ATCO to avoid conflicts in the airspace), the capacity of a given sector could be increased. This would move the role of human ATCOs from handling routine tasks to managing exceptional situations.

Security requirements are paramount in any ANS technical system. In addition to providing the highest levels of system availability and data integrity, unauthorized access must be prevented at any time via adequate authentication components. In a network-centric model, unauthorized access naturally poses a higher risk than in offline systems. However, these challenges can be overcome, for example, by introducing trusted third parties or by relying on proven cryptography algorithms (Kandukuri et al. 2009; Sabahi 2011; Zissis and Lekkas 2012).

Eventually, the data cloud paves the way for a service-oriented architecture (SOA) (Huhns and Singh 2005). This could break up the oligopoly structure of the ANS software market (Mueller et al. 2010). For technology providers, this means that the market entrance barrier regarding know-how would be lowered: In-depth expertise in monolithic integrated IT architecture would no longer be required. New technology providers could enter the field of ANS software, specialising on a single component like the Human Machine Interface (HMI). ANSPs would have the option of buying specific services instead of fully-integrated systems, which would decrease their dependency on monopolistic ANS software vendors, thus increasing an ANSP's bargaining power towards technology providers.

A service-oriented architecture (SOA) for ANSPs includes local ATC centres and site-depending infrastructure components (e.g. surveillance/radar equipment), connected via a (logically) centralized data layer (Figure 7 (a)). By moving certain services to a centralized layer while retaining local centres, this architecture would not explicitly require any closing of a physical ATC centre.

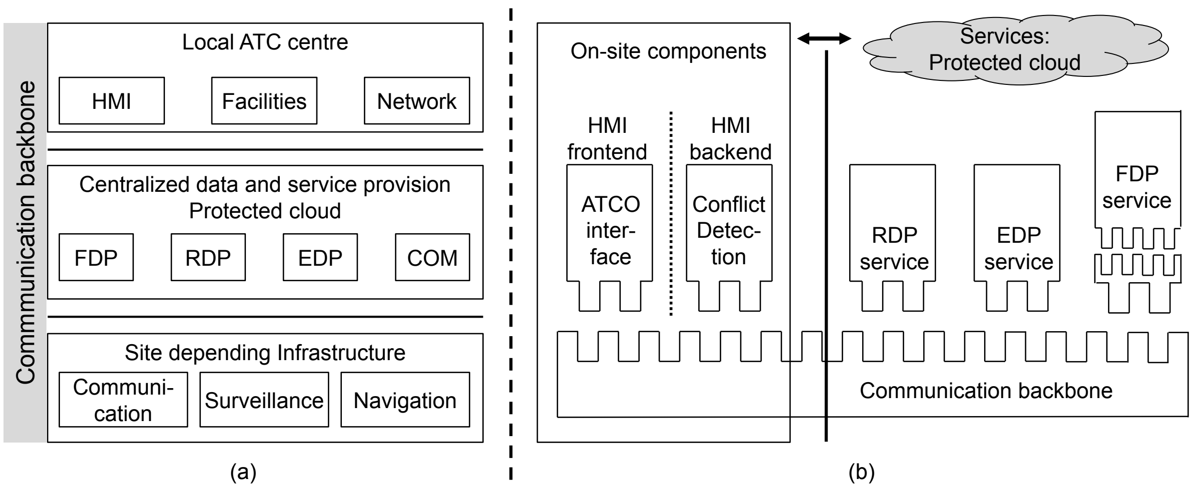


*Figure 7: A service-oriented architecture for ANSPs*

Figure 7 (b) shows a possible system architecture for an ANSP. The ANSP could use on-site HMI components, which may consists of a frontend (ATCO interface) and a backend (communication component) that receives RDP, EDP, FDP (connecting a legacy system via an adapter) as well as conflict detection services from external providers (Figure 7 (b)). Note that the conflict detection service can consume information from other cloud-based services such as FDP over the communication backbone. The enablers of such an architecture are centralized data provision as proposed by the

SWIM concept (SESAR Joint Undertaking 2011), and a communication backbone that defines interfaces for data exchange, to which all components adhere in an ATM system, including HMI and Data Processing Services.

In addition to cost-saving potential due to better systems maintainability and extendibility, SOA enables a greater degree of specialization: ANSPs can focus on a particular component of an overall ANS system and build specialized know-how in this area, while acquiring other system components from third parties. This may reduce the overall heterogeneity in ANS systems. For instance, if the diversity of HMIs is reduced to a few interfaces that are accepted and used by a great number of ANSPs, ATCOs working procedures and ATCO training could be standardized to a greater degree.

The key advantage of this architecture is that each ANSP can implement it within a timeframe that suits its own legacy situation. In other words, an ANSP can decide which components are to remain on-site, as an integrated system, and which services can be provided from the cloud. ANSPs with legacy systems, e.g. FDP systems, may be at the beginning of the transition to a SOA: FDP system would then receive RDP and EDP services from third-party providers, which would enable FDP to move from an integrated FDP component to a cloud-based FDP service. The separation of the integrated, on-site system parts from services provided via the cloud, and can be adjusted individually by each ANSP, as long as interoperability between ANSPs is provided via the communication backbone and the centralized data cloud (Figure 7 (b)). Thus, existing investments can be protected and systems can be replaced only when they are approaching the end of their lifecycle. Safety and availability issues are less severe with an evolutionary change approach than with big changes.

In the diffusion model of Rogers (1995), providing an architectural blueprint of a SOA for ANS systems increases knowledge about technological innovation potential. By showing how technological obstacles can be overcome with a concrete architectural proposal that takes specific industry requirements (e.g., security and the need for evolutionary change) into account, the perceived characteristics at the persuasion stage are likely to be convincing from a technological point of view. This increases the likelihood of an adoption in the decision stage. ANSPs who reject the transition for the time being, e.g. due to financial constraints, have the possibility to opt for a later adoption.

The proposed ICT innovation has some implications for the business model of ANSPs: For instance, interoperability between ANS systems enables dynamic sector allocation, which, as a consequence, would allow for temporary shutdown of an ATC centre when other ANSPs are capable of managing this sector. Even though the dynamic sector allocation is a cornerstone to achieve SES cost-efficiency, it means that ANSPs are likely to lose some of their revenues, especially since their services would become increasingly interchangeable. Especially ANSPs of smaller states may have to look for new business opportunities, since they might be faced first with the threat that at least parts of their currently controlled airspace might be managed by a neighbouring ANSP in the future. For example, a new business model could focus on providing training services to external ATCOs from other ANSPs.

## A.7 Conclusion and Outlook

The goal of this study is to reveal obstacles that make innovation in ANS so difficult and to contribute to the understanding of the technology diffusion process in the ANS industry. On this basis, ICT approaches are proposed to tackle the identified technological obstacles with the intention to actively influence the perception and behaviour of stakeholders. The findings show that reaching a decision point where technology is accepted (or rejected) in the ANS industry is bristled with obstacles to overcome different mental states of the involved stakeholders that are described in the model of Rogers (1995).

This study is one of the first to identify obstacles to innovation in an HRO. Whether the findings are generalizable to other HROs (e.g., nuclear power plants or hospitals) has to be investigated in further research. Still, the study provides a better understanding of technology adoption and diffusion in an under-researched domain and renders some new insights for both, industry ANSP decision makers and scientists. The identified obstacles may help practitioners define ICT strategies not only to tackle technical challenges, but also to consider the influence of political, economic and social stakeholders. Practitioners of the field may use the findings as an entry point to the creation of knowledge towards the development of ICT that enables enterprise transformation in the ANS industry.

The study has its limitations. It does not reflect the intertwining aspects of political, economic, social and technological aspects. Since this paper mainly focuses on ICT architecture to overcome technological obstacles, the implications of ICT architecture on the other PEST dimensions need further analyses. The concrete architectural proposal provides the discussion and negotiation vehicle to do so. Interview partners are members of one internationally recognized, yet small-sized ANSP. In order to validate the findings, interviews with other stakeholders from the ANS industry, for example representatives of ANS system providers and regulators, are needed.

Further research is required to better comprehend the industry-wide process of technology diffusion. In this sense, future work should also include the identification of additional innovation obstacles and look out for further enablers in the entire ANS industry. Additionally, enablers for economic, political and social obstacles need to be defined. Since no emphasis has been made considering the interfaces between stakeholders in the ANS industry, enterprise transformation aspect should be discussed under these aspects. Describing how incentive schemes could influence the ANS industry and its stakeholders could be a basis to describing requirements for increasing diffusion of innovation in this industry.

Finally, some more findings about successfully implemented solution designs would be of extraordinary value for deducing efficient and generalizable enterprise transformation mechanisms in an HRO environment. For these potential future endeavours this study can provide a substantial first step towards structuring the delicate and tricky situation of innovation management in the ANS industry.

# Paper B – Enterprise Architecture Artifacts As Boundary Objects - A Framework Of Properties

*Table 10: Bibliographical metadata on Paper B*

| Attribute | Value |
|---|---|
| Title | Enterprise Architecture Artifacts As Boundary Objects - A Framework Of Properties |
| Author(s) | Abraham, Ralf<br>University of St. Gallen, Müller-Friedberg-Strasse 8, 9000 St. Gallen, Switzerland<br>ralf.abraham@unisg.ch |
| Selected approach for order of authors | Sequence determines credit |
| Publication outlet | ECIS 2013 Completed Research |
| Publication type | Conference paper |
| Publication year | 2013 |
| Rating (Jourqual 2.1) | B |
| Publication status | Published |

*Abstract*

This paper uses the concept of boundary objects to derive hypotheses for the design of Enterprise Architecture (EA) artifacts, with the goal of supporting communication and coordination in enterprise transformation projects. Boundary objects are a useful concept to understand the coordinative role of artifacts in practice. Since enterprise transformation projects typically involve multiple communities of practice, communication and coordination are important success factors.

First, a set of 11 boundary object properties is identified via a structured literature review. After a focus group consisting of nine EA practitioners, the set is extended to 12 properties: Modularity, Abstraction, Concreteness, Annotation, Versioning, Shared Syntax, Accessibility, Up-to-dateness, Malleability, Stability, Visualization, and Participation.

Finally, the set of boundary object properties is linked to three classes of EA artifacts (repositories, matrices, and diagrams) from the TOGAF framework, and three hypotheses are derived for the design of EA artifacts in order to become boundary objects capable of crossing a given knowledge boundary (syntactic, semantic, and pragmatic). The hypotheses argue for a common syntax, community-specific views, and joint editing and collaboration capabilities.

*Keywords*

Boundary Objects, Enterprise Architecture Management, Literature Review

## B.1 Introduction

Enterprises face an increasingly complex environment which forces them to undergo fundamental change, in other words transform themselves (Rouse 2005b). The causes for such transformation efforts range from business- or IT-driven initiatives inside the enterprise to external events such as the changes in customer behavior or regulatory requirements. Transformation involves a wide and diverse variety of stakeholders, from business to IT to corporate functions, and thus highlights the need for coordination. Yet despite the relevance of enterprise transformation, reports indicate high failure rates across a broad range of domains (Dietz and Hoogervorst 2008). Dietz and Hoogervorst (2008) name a lack of coordination in enterprise transformation projects as a key reason for the high failure rates.

Several approaches exist that aim at improving organizational communication and coordination. One of these approaches is enterprise architecture (EA). EA highlights two key aspects: Next to providing principles that guide design by restricting design freedom, EA aims at providing a high-level overview of enterprises in the form of models, e.g. as-is models, to-be models, or roadmaps. Thus, EA is considered to be a supplier of information, capable of highlighting dependencies and supporting coordination of enterprise transformation (Harmsen et al. 2009; Ross et al. 2006; Tamm et al. 2011). However, in practice, EA artifacts often fail to be used by communities other than IT to communicate.

To better understand how coordination can be supported via artifacts – in this case EA artifacts – the concept of boundary objects from sociological literature is used. Boundary objects provide interfaces between different organizational communities of practice and thus are considered to be “a useful theoretical construct with which to understand the coordinative role of artifacts in practice” (Lee 2007). Star, who coined the term in 1989, asserts that the concept is most useful at the organizational level (Star 2010). Thus, the boundary object concept may help support a partial aspect of coordination in enterprise transformation, namely: Supporting cross-boundary communication via artifacts.

This paper uses a two-step research approach: First, a structured literature review identifies a set of boundary object properties. Second, properties of architectural artifacts that already take the role as boundary objects are discussed in a focus group of enterprise architects. Based on these inputs, properties are mapped to architectural artifacts of the TOGAF framework, and hypotheses are derived to design EAM artifacts as boundary objects. Since EAM artifacts shall eventually be designed to implement certain properties (based on contextual factors), the properties should be understood as desired rather than defining properties. The research questions of this paper are the following:

(1) Which properties do boundary objects have?
(2) How can these properties be applied to EA artifacts, in order to turn them into boundary objects?

The remainder of this paper is structured as follows. Section two introduces conceptual foundations, particularly on boundary objects. Research Methodology and results are discussed in sections three and four, respectively. Section five discusses implications for EA artifact classes as boundary objects. The paper ends with a section discussing limitations and offering a conclusion.

## B.2 Conceptual foundations

### B.2.1 Communities of practice

"Communities of practice" is a term coined by Wenger (2000) to describe a community of people that (1) share a joint area of concern (e.g., share the same tasks in an organization or are interested in the same topics), (2) regularly interact within a set of community-specific norms and relations, and (3) possess a shared repertoire of resources such as languages, methods, tools, stories or other communal artifacts. In an organizational setting, such communities may correlate with certain departments, like business analysis or data warehouse architecture. However, also people working in different departments may form a community of practice, for example project managers. The essential characteristic of a community of practice is "practice" – regular interaction and a shared repertoire of resources to work the joint area of concern – rather than the same job title.

### B.2.2 Boundary objects

Since boundary objects are the central theme of the following literature review, they will be given special attention (Webster and Watson 2002). The term "boundary object" was originally introduced by Star and Griesemer (1989). Boundary objects are abstract or physical artifacts that support knowledge sharing and coordination between different communities of practice by providing interfaces. Table 11 gives a chronologically ordered selection of definitions.

*Table 11: Selected definitions of the concept "boundary object"*

| Source | Definition |
|---|---|
| (Star and Griesemer 1989) | Boundary objects are objects which are both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. They are weakly structured in common use, and become strongly structured in individual site use. These objects may be abstract or concrete. They have different meanings in different social worlds but their structure is common enough to more than one world to make them recognizable, a means of translation. |
| (Karsten et al. 2001) | Boundary objects (Star & Griesemer, 1989; Star, 1993) are physical objects such as design drawings, maps, contracts, learning materials, etc that are used to facilitate cooperation while allowing diversity in interpretation. |
| (Dodgson et al. 2007) | Boundary objects mediate interactions between different communities of practice by providing a common basis for conversations about solutions to problems. |
| (Winter and Butler 2011) | By identifying 'lowest common denominators,' critical points of agreement, or shared surface referents, boundary objects provide a sufficient platform for cooperative action – but they do so without requiring the individuals involved to abandon the distinctive perspectives, positions, and practices of their 'base' social world. |
| (Nicolini et al. 2012) | Boundary objects are defined by their capacity to serve as bridges between intersecting social and cultural worlds. Anchored in, and thus meaningful across, these worlds, they create the conditions for collaboration while, by way of their interpretive flexibility, not requiring "deep sharing." |

These definitions highlight the two central aspects of boundary objects: Interpretive flexibility and retaining a community's identity. (1) Interpretive flexibility: Boundary objects provide interfaces between communities of practice who are thus able to coordinate their work. When they are used for a common purpose of multiple communities of practice, boundary objects provide a common point of reference and are thus "weakly structured" (Star and Griesemer 1989). However, each of the communities involved uses the boundary object, on a more detailed level, for its specific purposes, therefore making the object "strongly structured in individual site use" (Star and Griesemer 1989). (2) Retaining identity: While providing lowest common denominators, a shared point of reference, boundary objects do not aim to level the differences between the involved communities (i.e., to replace any other objects or practices the communities work with): They rather acknowledge each community's individual identity and allow it to preserve the practices of its social world.

Carlile (2002) identified four classes of boundary objects based on Star and Griesemer's (1989) original classification: First, *repositories* provide a common reference point by making available uniform data, measures, and labels (e.g., a shared database). Second, s*tandardized forms and methods* provide a shared format or template (e.g., a D-FMEA form in engineering, or any other template), or a common methodology such as SCRUM. Third, *objects* (e.g., physical prototypes) and *models* (e.g., sketches, assembly drawings, mockups) are simple or complex representations of real-world things. Fourth, *maps* (e.g., Gantt charts, process maps, simulation tools) that identify dependencies and boundaries between different objects and models. Maps support cross-functional problem solving. For example, a group of engineers with different professional backgrounds negotiate a design solution using a computer simulation model.

Carlile (2004) further distinguishes three types of knowledge boundaries between communities of practice that become increasingly difficult to cross: Syntactic, semantic, and pragmatic boundaries. Syntactic boundaries exist due to different vocabulary between communities of practice; they can be crossed by providing communities with a *common lexicon*, thereby introducing common terminology. To cross semantic boundaries, the involved communities must additionally create *common meaning* by identifying their differences and dependencies (e.g., with the help of a boundary object, they can identify where their perceptions differ). A pragmatic boundary finally adds differences not only in meaning, but also in interests – each involved community has its own political agenda and sees its knowledge ”at stake” (Carlile 2004). Boundary objects in this case support a negotiation process, where the involved communities attempt to find a mutually acceptable solution to reach *common interests*.

Crossing a higher-level boundary invariably involves crossing lower-level boundaries: In order to identify differences in meaning at a semantic boundary, a common terminology must be provided first. Being able to negotiate common solutions at a pragmatic boundary also involves crossing syntactic and semantic boundaries. At a syntactic boundary, a common repository may suffice to establish common terminology, whereas at a semantic boundary, standardized forms and methods allow identifying differences in meaning and dependencies (Carlile 2002). At a pragmatic boundary, ”jointly transformable” (Carlile 2004) boundary objects like physical objects and prototypes allow for direct modification and provide immediate feedback to the involved communities of practice, thereby supporting the negotiation process. This is why this class is reported to be most effective when faced with pragmatic boundaries (Bechky 2003; Carlile 2002).

In any case, boundary objects emerge from concrete, existing objects in organizations. The adoption of an object as a boundary object depends on a wide range of contingency factors, and an object that has in one situation success as a boundary object may fail to do so when the situation changes: E.g., when new communities are involved or concerns change (Carlile 2002). In fact, Levina and Vaast (2005) explicitly distinguish between “designated boundary objects” and “boundary objects-in-use”. Thus, boundary objects alone are not sufficient to enable communication and coordination between different communities of practice; rather they are tools that are used at the discretion of organizational actors.

These properties also set boundary objects apart from taxonomies or ontologies: A taxonomy may be an instance of the boundary object class of repositories, while an ontology, describing the construction of a complex system like an enterprise (Dietz and Hoogervorst 2008), may be an instance of the boundary object class of maps. However, in order to work as boundary objects, taxonomies and ontologies must be actually used by communities of practice to cross the knowledge boundaries between them: Only when they are locally useful to each community, while at the same time provide a common point of reference for several communities, can taxonomies or ontologies act as boundary objects.

### B.2.3 Enterprise architecture management

"Architecture", according to the ISO/IEC/IEEE Standard 42010, is concerned with describing a systems fundamental structure, as well as providing guidelines for its evolution (ISO/IEC/IEEE 2011). Enterprise architecture management (EAM) aims at purposefully designing an enterprise's architecture in pursuit of its strategic goals. Due to its enterprise-wide focus, EAM typically involves many diverse communities of practice (Dijkman et al. 2004; Kurpjuweit and Winter 2007) and is considered a means to support the coordination of enterprise transformation (Harmsen et al. 2009; Ross et al. 2006; Tamm et al. 2011). Concentrating on the descriptive aspect of architecture (a system's fundamental structure), enterprise architecture (EA) supports coordination by providing a high-level overview of enterprises in the form of models, e.g. as-is models, to-be models, or roadmaps. EA models are thus potential boundary objects that could improve communication between different communities of practice. One of the most widely distributed EA frameworks is TOGAF (The Open Group 2011).

## B.3 Research Methodology

### B.3.1 Literature review

In order to focus on boundary objects in the organizational context and to highlight an information systems perspective, the search scope was set to include highly recognized journals from the fields of information systems, organizational studies, and general management. In addition, major information systems (IS) conferences have been included. Focusing on journals seemed appropriate because existing boundary object literature dates back over two decades, and has therefore, unlike cutting-edge developments, had time to evolve from conference papers to journal articles. This quality-oriented approach, focusing on leading journals but reaching beyond the field of IS proper, is also recommended by Webster and Watson (2002). The search term used was "boundary object" (including the plural form "boundary objects"), and the searched fields were title and abstract. Table 12 summarizes the searched outlets. The journal "Organization Science" is included in both the second and the third literature source, therefore hits from this outlet only count towards the second category.

*Table 12: Sources included in the literature review*

| No. | Literature Source / Topic Focus | Hits |
|---|---|---|
| 1 | AIS Senior Scholars' Basket of Journals (Association for Information Systems 2011) / IS | 11 |
| 2 | "Leading Management Journals" (Barreto 2010, p. 258) / General Management | 9 |
| 3 | Jourqual 2 Ranking, Top 10 Journals in "Human Resources and Organization", (Schrader and Hennig-Thurau 2009, pp. 194-195) / Organizational studies | 1 |
| 4 | Additional outlets from the AIS Electronic Library: Scandinavian Journal of Information Systems, Proceedings of the International conference on Information Systems (ICIS), Proceedings of the European conference on Information Systems (ECIS) / IS | 4 |

This search yielded a total of 25 articles. 4 articles have been removed as they only marginally covered boundary objects and gave little indication on their properties. A forward and backward search added 5 articles, thereby bringing the final set to 26 articles. These articles were thoroughly analyzed in order to identify boundary object properties. All candidate properties were collected, and the final list was continuously refined by adding, renaming or deleting properties while scanning the articles. When the final set of properties had reached a stable state, the scanning process was ended.

### B.3.2 Focus group

Boundary object properties have been discussed in a two-hour focus group session that took place in September 2012 in Switzerland. Focus groups are a valuable tool to evaluate researchers' analytical conclusions (Tremblay et al. 2010) and to measure the level of consensus within a group (Morgan 1997). The group consisted of nine panelists from different German and Swiss enterprises mainly in the financial services or energy industry. The panelists had several years of working experience in the fields of enterprise architecture, data architecture, IT architecture or IT strategy.

First, the boundary object concept was briefly introduced. The panelists were then asked to name EA artifacts from their enterprises which they considered boundary objects. In order to have an open discussion and gain additional insights, the panelists were not presented with the list of properties identified from the literature review; instead, boundary object properties were collected in a bottom-up manner based on concrete boundary objects from the panelists' enterprises. After several examples had been collected, all participants engaged in an open discussion on properties of these EA artifacts and factors that influenced their usage as boundary objects. The discussion was moderated by the author. At the end of the session, the boundary object properties identified in the discussion were consolidated by the moderator.

## B.4 Results

### B.4.1 Literature Review

In the following, a consolidated definition of the identified boundary object properties is given. Figure 8 provides a summary of the literature review, giving concrete examples of boundary objects and the communities of practice involved, and mapping the identified properties to literature sources.

*Modularity*. In the context of boundary objects, modularity enables involved communities to attend to specific areas of a boundary object independently from each other, like attending to individual portions of an ERP system. Communities may use the boundary object for aspects of specific importance to them, without disturbing or interfering with other communities' use of the boundary object (Pawlowski and Robey 2004; Star 2010).

*Abstraction*. Boundary objects are "weakly structured in common use" (Star and Griesemer 1989). Boundary objects serve the interests of all involved communities of practice by providing a common reference point on a high level of abstraction. Local contingencies are eliminated from high-level views, in order to highlight the commonalities (Gasson 2006; Levina and Vaast 2005).

*Concreteness*. Boundary objects are "strongly structured in individual site use" (Star and Griesemer 1989). Boundary objects are able to address specific problems for specific communities of practice. Communities are able to specify their concerns and express their knowledge related to the problem at hand. Thus, interpretive flexibility is provided. Applying the boundary object to their concrete problems, communities are able to learn about their differences and dependencies (Carlile 2002; Pawlowski and Robey 2004).

| **Author(s)** | **Boundary object example(s)** | **Communities of practice involved** | Modularity | Abstraction | Concreteness | Annotation | Versioning | Shared syntax | Accessibility | Up-to-dateness | Malleability | Stability | Visualization |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (Barrett and Oborn, 2010) | Software specification, timelines | Jamaican and Indian software development teams | O | | | | | | | | O | O | O |
| (Bechky, 2003) | Technical drawings, machines | Engineers, technicians, and assemblers | | | O | | | | | | | | |
| (Boland and Tenkasi, 1995) | No specific example; conceptual paper | No specific example; conceptual paper | | | | | | | O | | | | O |
| (Carlile, 2002) | D-FMEA forms, CAD models | Design, engineering, and production | | | O | | | | | O | O | | |
| (Carlile, 2004) | 3-D car model | Engineering groups for different car components | | | | | | | | | O | | |
| (Dodgson et al., 2007) | Simulation tools | Fire fighters, building engineers | | | | | | O | | | | | |
| (Doolin and McLeod, 2012) | Prototype for database solution | Project manager, outsourcing contract manager, vendor representative, senior developer | | | | | | O | | | O | | |
| (Gal et al., 2008) | 3-D CAD model | Architects, building contractors | | | | | | O | | | | | |
| (Gasson, 2006) | Electronic document library | Business process redesign, IT system analysis | | O | | | | | | | | | |
| (Henderson, 1991) | Sketches, CAD models, data bases | Management, design, production | | | O | | | | | | | | O |
| (Karsten et al., 2001) | Technical specifications document | Engineering project team, customer organization | | | | O | O | | O | O | O | O | |
| (Levina, 2005) | Sales presentation, web page mockups | Internet consulting company, publishing company | | | O | | | | O | O | | | O |
| (Levina and Vaast, 2005) | Case 1: use case scenarios; case 2: best practice database, FAQ | Case 1: internet consulting company, publishing company; case 2: headquarters, local offices | O | O | O | | | | O | O | | | |
| (Mark et al., 2007) | Project fact sheets, project plans | Project managers, systems engineers | | | | | O | | | | | | |
| (Mattila et al., 2012) | Enterprise system for project staffing | Managers: Staffing, line, project; Employees | | | | | | O | O | | | | |
| (Newell and Edelman, 2008) | Project documentation (lessons learnt) | Projects (sewage / enhanced water treatment) | | | | | | O | | | | | |
| (Nicolini et al., 2012) | Prototype: bioreactor; visual slides with experimental results | Biologists, sensor engineers | O | | O | | | | | | | | |
| (Østerlund, 2008) | Whiteboard | Doctors, nurses | O | | | | | O | | | | | |
| (Pawlowski and Raven, 2000) | Environmental information system | Engineers, lawyers/lobbyists, auditors | | | | | | | | | | | |
| (Pawlowski and Robey, 2004) | Shared IT system | Sales, accounting, risk, IT departments | O | O | O | | | O | | | | | |
| (Puri, 2007) | Geographic information systems (GIS) | Scientists, local authorities, local communities | | | | | | O | | | | | O |
| (Rajão and Hayes, 2012) | Geographic information systems (GIS) | Scientists, federal authorities, local rangers | | | | | | O | | | | | |
| (Star, 2010) | No specific example; conceptual paper | No specific example; conceptual paper | O | | | | | | | | | | |
| (Star and Griesemer, 1989) | Species descriptions, maps | Museum administrators, scientists, laymen | | O | | | | | | | | | |
| (Winter and Butler, 2011) | Human genome map | Biologists, data analysts, administrators | O | | O | | | O | | | O | | |
| (Yakura, 2002) | Visual timelines | IT consultants, client firm (utility industry) | | | O | O | | | | | | O | O |

*Figure 8: Identified boundary object properties in the literature review*

*Annotation*. Boundary object can be enriched with additional information by individual communities of practice in order to provide context for local use. Boundary objects are durable and stable, yet give the involved communities the option to add local information (Karsten et al. 2001; Yakura 2002).

*Versioning*. Changes can be traced and additional context is provided by reconstructing the chronological evolution of the boundary object. This is similar to the use of a software versioning / revision control system in software engineering. A history of changes can be reconstructed, along with their rationale (Karsten et al. 2001; Mark et al. 2007).

*Shared syntax*. A common schema of information elements is provided, so that local use of information objects is uniform across communities of practice. Shared syntax may be supported by a common information model, or shared notation conventions (e.g., standardized bug tracking forms that are used across an organization, or common modeling notations such as UML) (Dodgson et al. 2007; Pawlowski and Robey 2004).

*Accessibility.* The boundary object is readily accessible for the involved communities (i.e., they are granted access rights or they are supplied with physical representations such as printouts). This also includes informing interested communities about the boundary object using appropriate communication channels and other measures aimed at helping communities use the boundary object, such as training measures (Boland and Tenkasi 1995; Levina 2005).

*Up-to-dateness*. The information contained in the boundary object is up-to-date. This includes timely communication of changes to the involved communities, as well as responsibilities and processes for updating the boundary object (Carlile 2002; Karsten et al. 2001).

*Malleability*. Boundary objects are jointly transformable to support detecting dependencies and negotiating solutions. Communities of practice thereby receive immediate feedback on changes and see the dependencies of their work with other communities' areas of concern (Carlile 2004; Doolin and McLeod 2012).

*Stability*. The structure and underlying information objects of a boundary object remain stable over time. Despite different local uses and annotations, boundary objects are brought to closure, i.e. they provide a stable reference frame. Closure reflects an agreement on the parts of the boundary object that is of interest to all involved communities (Karsten et al. 2001; Yakura 2002).

*Visualization*. The boundary object does not rely on verbal definitions, but possesses a graphical or physical representation (e.g., a drawing or a prototype). A graphical representation of boundary objects helps acquire interpretive flexibility and foster dialogue between communities of practice, supporting deliberations about further actions. By using techniques to improve the cognitive effectiveness (Moody 2009), a boundary object can be made more accessible to different communities and easier to use and understand (Boland and Tenkasi 1995; Henderson 1991).

### B.4.2 Focus group

During the focus group session, the examples of boundary objects provided by the panelists fell primarily into the categories of repositories, models, and maps. Examples of repositories are various fact sheets or enterprise-wide information object catalogues. Examples of models were business object models or data warehouse layer models, while the most frequent examples of maps were capability maps (establishing a link between business and IT capabilities) and process maps. For example, a sheet concerning figures in an insurance company is used both on the business side to identify attributes of an insurance contract (e.g., premiums and conditions), but the same sheet is also used in the IT department to map those attributes to database fields. As a boundary object, this sheet crosses the syntactic boundary between business analysts and the IT department by providing a common lexicon. Perhaps the most visible indication of the boundary object character of this sheet is the fact that it hangs both in the CFO's and the developer's office.

In the case of models and maps, panelists called for a "less is more" approach, warning against cluttering process maps or capability maps and thereby compromising clarity and ease-of-understanding. Instead, they opted for a use of detailed views to render models useful to individual communities of practice that require information at a greater level of detail, while offering the higher level of abstraction to address the common concerns of multiple communities of practice. Panelists also mentioned that a clear and appealing visualization (e.g., color coding or distinctive shapes), particularly in the case of models, as essential for the adoption and the use of boundary objects.

Another aspect the panellists stressed is stability: A constantly changing object fails to gain legitimacy and tends to be ignored. On the other hand, a wide focus involving many communities of practice and changes in the business mandate periodic updates, otherwise information would be outdated and the concerns of certain communities could no longer be addressed. To balance between the desired properties of stability and up-to-dateness, panellists recommended a dedicated change management and release process. With such a process, change requests are collected, discussed, evaluated and periodically lead to new releases. Thus, there is always an official version available, while the object can still be updated regularly.

The panel also stressed that boundary objects need to involve a broad range of communities of practice, and should also be used by top management. Their argument was that this would strongly increase acceptance and use of a boundary object. This property is named "participation" to reflect both the participation of all relevant communities in the creation, maintenance and use of the boundary object, and to also emphasize the role of top management participation (cf. the construct of (EA stakeholder) participation by Schmidt and Buxmann (2011)).

*Participation*. Relevant communities if practice should be involved in the creation and maintenance of the boundary object. Boundary object users should also include top management.

While the properties of abstraction, concreteness, stability and visualization had already been identified in the literature review, the property of participation extends the final set to 12 properties.

## B.5 Discussion

In order to examine the role of EA artifacts as boundary objects, the classification of EA artifacts from the TOGAF framework (The Open Group 2011) is used. TOGAF distinguishes between three classes of architectural artifacts: Catalogs representing lists of things, matrices showing relationships between things, and diagrams depicting things. Catalogs can thus be mapped to the boundary object class of repositories, matrices to the class of maps, and diagrams to the class of objects and models.

Since the capability to cross a syntactic boundary is a precondition to cross either the semantic or the pragmatic boundary, catalogs form the foundation for the other classes of EA artifacts (matrices and diagrams). Catalogs help to establish the common lexicon required for different communities of practice to communicate. Important properties for these catalogs are stability, accessibility, and up-to-dateness. Release management processes can help to control the frequency of changes while regularly updating the contents (thus balancing between stability and up-to-datenesss), however, the basic constructs in an enterprise (e.g., information objects and business concepts) are likely to have a higher degree of stability than more complex boundary objects such as matrices or diagrams. Accessibility may be supported by making catalogs centrally available and referencing them in matrices and diagrams. By providing official releases, synchronization problems with outdated local versions may also be avoided. Catalogs highlight the boundary object property of modularity: They represent objects at a given degree of abstraction, but allow different communities of practice to independently address those parts that are relevant to community-specific concerns (e.g., a shared database or the insurance company's figure sheet introduced in section 4.2).

Communities of practice face a semantic boundary when enterprises are faced with environmental changes and have to transform. New requirements make differences and dependencies unclear and meanings ambiguous. Here, the EA artifact classes of matrices and diagrams can be helpful to arrive at a common meaning. In addition to the desired properties of catalogs like stability, accessibility and up-to-dateness, properties like annotation and versioning are helpful in enriching matrices and diagrams with context information and allowing comparisons with historical versions. This makes the provenance of these artifacts visible to the involved communities of practice and provides additional information to identify new differences and dependencies. Especially for the artifact class of diagrams, attention should be given to visualization properties, as these may be helpful in detecting and communicating dependencies to stakeholders (The Open Group 2011).

Matrices and diagrams highlight the necessary balancing between the boundary object properties of concreteness and abstraction: In order to be useful to individual communities of practice, boundary objects have to be interpretable by individual communities to address their specific concerns. At the same time, they also have to contain information concerning several communities at a sufficiently high level of abstraction to form a common point of reference. Community-specific views can be used to provide this balance, where different communities of practice share a view that identifies their lowest common denominator, while individual communities rely on specific views for information on their particular concerns at a lower level of abstraction. Special consideration must be given to maintain consistency and smooth transitions between these views.

Finally, when communities of practice encounter pragmatic boundaries and are required to negotiate common interests and solutions, the boundary object property of malleability is central. This property is available in objects that can be jointly transformed and worked upon, such as physical objects, simulation models or prototypes. In the case of EA artifacts, this property is very hard to implement, due to the intangible and conceptual nature of these artifacts. One approach may be to provide a physical representation of these artifacts (e.g., printouts) in order to allow joint editing and annotating; or to provide collaboration capabilities to the same effect. However, crossing a pragmatic boundary usually involves significant political efforts, since powerful communities of practice are interested in protecting their knowledge and influence. Boundary objects in this case are tools that are manipulated by organizational actors in pursuit of their interests. Summarizing, the following hypotheses are derived for EA artifact classes to cross syntactic, semantic, and pragmatic boundaries, respectively:

(1) To cross syntactic boundaries, the EA artifact class of catalogs needs to provide properties like stability, accessibility, and up-to-dateness. (2) To cross semantic boundaries, the EA artifact class of matrices and diagrams needs to offer community-specific views and supply context information. (3) To cross pragmatic boundaries, the EA artifact class of matrices and diagrams needs to have joint editing and collaboration capabilities.

## B.6 Summary

The contribution of this paper is the identification of a set of 12 boundary object properties by means of a structured literature review and a focus group with enterprise architects. This set provides the framework for a more detailed analysis of possible boundary objects encountered in practice, and design implications can be formulated referencing these properties. Three hypotheses have been derived for the design of various classes of EA artifacts as boundary objects.

Regarding limitations, the paper at hand is still predominantly conceptual, having collected boundary object properties primarily from literature. The properties are not equally distributed over the analyzed sources, with many properties mentioned only in a third of all sources. This implies that the properties vary in importance, and future research needs to identify which properties are relevant to cross which knowledge boundaries. Therefore, caution must be taken when using the identified properties as a basis for EA artifact construction. Also, the derived hypotheses have to be tested, by applying them to existing EA artifacts and examining their effectiveness in coordinating between communities of practice. Special consideration must be given to contingencies, e.g. between which communities of practice is coordination supported by an EA artifact, which knowledge boundaries are involved, and the overall characteristics of the transformation project. A general limitation of the boundary object concept must also be mentioned: Only some communication and coordination issues between communities of practice can be resolved by artifacts. Particularly when differing interests are involved and pragmatic boundaries exist, coordination is much more likely performed by humans, who perform a function as "boundary spanners" and may use certain boundary objects to support the negotiation process.

For researchers, determining where boundary objects have to be supplemented by other coordination mechanisms in an enterprise transformation project is an important avenue for further research, as well as how EA artifacts interact with other boundary objects in enterprise transformation. Moreover, the interdependencies between the identified properties have to be better understood. The set of boundary object properties is an initial one, yet it provides an important starting point for further research, which may lead to an evolution of this set. For managers, the derived hypotheses can give preliminary indications on how to enhance communication in their transformation projects.

*Acknowledgement*

This work has been funded by the Swiss National Science Foundation (SNSF).

# Paper C – Can boundary objects mitigate communication defects in enterprise transformation? Findings from expert interviews

*Table 13: Bibliographical metadata on Paper C*

| Attribute | Value |
|---|---|
| Title | Can boundary objects mitigate communication defects in enterprise transformation? Findings from expert interviews |
| Author(s) | Abraham, Ralf[1]; Niemietz, Hella[2,3,4]; de Kinderen, Sybren[4]; Aier, Stephan[1]<br>[1]University of St. Gallen, Müller-Friedberg-Strasse 8, 9000 St. Gallen, Switzerland<br>[2]CRP Henri Tudor, 29, avenue J.F. Kennedy, 1855 Luxembourg, Luxembourg<br>[3]Radboud University Nijmegen, Heyendaalseweg 135, 6525 AJ Nijmegen, The Netherlands<br>[4]EE-Team, Luxembourg, Luxembourg<br>ralf.abraham@unisg.ch, hella.niemietz@tudor.lu, sybren.dekinderen@gmail.com, stephan.aier@unisg.ch |
| Selected approach for order of authors | Sequence determines credit |
| Publication outlet | Proceedings of the 5th International Workshop on Enterprise Modelling and Information Systems Architectures (EMISA 2013) |
| Publication type | Conference paper |
| Publication year | 2013 |
| Rating (Jourqual 2.1) | C (Lecture Notes in Informatics (LNI) (der Gesellschaft für Informatik)) |
| Publication status | Published |

*Abstract*

Inappropriate communication is a major threat to enterprise transformations. While enterprise architecture (EA) models may be helpful to support communication, these models are often tailored to the needs of specialists like enterprise architects. Based on empirical data from 12 expert interviews, we analyze how EA models can become boundary objects that span knowledge boundaries and alleviate communication defects among heterogeneous stakeholder groups in enterprise transformations. We contribute a framework that maps six communication defects to three knowledge boundaries and to 12 boundary object properties as a foundation for future EA model design. Our findings also indicate that EA models alone are not sufficient for overcoming communication defects, but that facilitators like architects are needed in addition.

*Keywords*

n/a

## C.1 Introduction

Induced by various environmental pressures (originating from markets, regulators, customers etc.), enterprises face a constant need for change that often affects large parts of an enterprise. This kind of large-scale change is referred to as *enterprise transformation* (Rouse 2005b). An enterprise transformation typically is a collaborative endeavor of diverse stakeholder communities. These communities are diverse with respect to their knowledge, values, and goals. The need for collaboration among diverse communities is well-recognized in organizational literature (Carlile 2004; Karsten et al. 2001; Nicolini et al. 2012). To coordinate collaborative efforts during enterprise transformation, communication is a key success factor. Conversely, *communication defects* are a major threat to successful transformation. Communication defects lead to delays in transformation, increases in costs, and ultimately to struggles or even failure of transformation (Ford and Ford 1995; Harmsen et al. 2009).

Enterprise Architecture (EA) models support such communication (Valorinta 2011). In line with Winter and Fischer (2007), we understand an EA model to be a representation of an as-is or to-be state of an organization in its business to IT stack. However, we argue that not all EA models are particularly suitable for mitigating communication defects among diverse communities in enterprise transformations. Particularly, a model cannot be considered separately from its context of use: the role of the modeler (in our case: the architect) is paramount for the usefulness of EA models (Stirna and Persson 2012), while at the same time the fitness of a particular EA model depends on factors such as the addressed community or the purpose and scope of the model (Anaby-Tavor et al. 2010). Therefore, we take a boundary object perspective to analyze how EA models can help to prevent communication defects in enterprise transformations. Boundary objects, a concept from organizational science (Star and

Griesemer 1989), aim at providing interfaces between different communities of practice and thus support knowledge sharing communication.

Our research question is the following: *To what extent can communication defects in enterprise transformations be mitigated by using EA models as boundary objects?*

In addressing this question, we build upon a set of boundary object properties pertaining to both (1) the model itself, and (2) the role of the architect, and discuss to what extent these properties can address communication defects in enterprise transformations. In addition to this theoretical grounding of our research, we provide empirical grounding of the proposed boundary object properties by illustrating each property with qualitative data on practical modeling experiences from senior enterprise architects. In so doing, we extend our earlier work (Abraham 2013; Niemietz et al. 2013) by (1) explicitly linking the role of the enterprise architect to boundary objects, (2) applying the boundary object perspective to specifically mitigate communication defects, and (3) providing an empirical grounding of the theoretically-derived boundary object properties found in Abraham (2013).

Note that work has been done on models that involve different stakeholders, prominently by (Stirna and Persson 2012; Stirna et al. 2007). Yet, this work concerns collaborative modeling in general, while our focus is on EA models' application as far as they involve different stakeholder communities. Furthermore, work on model quality (Krogstie 2012; Krogstie et al. 2006; Moody 1998; Nelson et al. 2012) provides properties to assess both the process of modeling as well as the resulting model itself (Moody 2005). However, in Moody (2005) the focus is on evaluating the model quality for a single user community, while in the paper at hand we are interested in the interplay among different communities. The rest of this paper is structured as follows.

In section two, we discuss conceptual foundations of communication defects and boundary objects. Section three presents our research approach. In section four, we describe, based on empirical data, how various boundary objects have helped architects in overcoming communication defects. We discuss our findings, especially with regard to the role of the architect, in section five. Section six concludes our paper.

# C.2 Conceptual foundations

## C.2.1 Communication defects in enterprise transformations

Change-management literature shows that transformations often fail because of poor or too little communication (Barrett 2002; Gilsdorf 1998; Kitchen and Daly 2002; Kotter 1995). Elving (2005) for example points out that "poorly managed change communication results in rumors and resistance to change". This raises a need to prevent or at least mitigate pitfalls such as communication defects among the involved communities (Harmsen et al. 2009).

The EA function is consistently positioned as an instrument to improve communication in enterprise transformations (Tamm et al. 2011; van der Raadt et al. 2010). Yet, recent research shows that communication defects also occur in EA-driven enterprise transformations. They contribute significantly to the struggling or failure of EA-driven enterprise transformations (Niemietz et al. 2013). Examples of such transformation struggles include delays in the transformation and not fulfilling the transformation goals. Based on qualitative data from interviews with mostly enterprise architects, Niemietz et al. (2013) provide a list of communication defects. They categorize those specific defects into three groups, namely *lack of communication*, *inappropriate communication* and *over-communication*. In the paper at hand we focus on the question of how EA models can be employed to overcome inappropriate communication. Inappropriate communication is found in the following communication defects (Niemietz et al. 2013): inappropriate communication means, inappropriate communication style, no shared frame of reference, communication against the transformation, non-aligned implicit and explicit communication, and dishonest communication.

The finding that communication defects are an important reason for struggles in or failure of EA-driven enterprise transformations is particularly interesting when considering that EA models are supposed to support communication (Valorinta 2011). This raises the question to what extent communication defects in enterprise transformations can be mitigated by using EA models, and whether existing models need to be changed.

## C.2.2 Boundary objects

The differences of communities regarding their knowledge, values, and goals are manifested in knowledge boundaries. Carlile (2004) distinguishes three types of such boundaries: syntactic, semantic, and pragmatic boundaries. *Syntactic boundaries* exist due to different terminology among communities. *Semantic boundaries* are boundaries of interpretation, which can be crossed by identifying differences and dependencies of the communities and the creation of common meaning based on common terminology. *Pragmatic boundaries* are political boundaries. They represent differences in goals and interests. Communities have their own agenda and see their power position "at stake" (Carlile 2004).

The three boundary types have an increasing level of complexity with syntactic boundaries at the lowest and pragmatic boundaries at the highest level. Crossing a higher-level boundary invariably involves crossing lower-level boundaries: To identify differences in meaning at a semantic boundary a common terminology must be provided first; being able to negotiate common solutions at a pragmatic boundary also involves crossing syntactic and semantic boundaries.

To aid in crossing knowledge boundaries, boundary objects (originally introduced by Star and Griesemer (1989)) are a widely-employed concept. Boundary objects are abstract or physical artifacts that support knowledge sharing and collaboration between different stakeholder communities by providing interfaces for communication. Examples of boundary objects include physical objects such as prototypes (Carlile 2004), intangible objects like shared IT applications (Pawlowski and Robey 2004), maps and models (Star and Griesemer 1989), and abstract conceptualizations such as standardized forms and repositories (Carlile 2004; Star and Griesemer 1989). According to Winter and Butler (2011), "boundary objects provide a sufficient platform for cooperative action – but they do so without requiring the individuals involved to abandon the distinctive perspectives, positions, and practices of their 'base' social world". Boundary objects are emergent, and "designated boundary objects" only become "boundary-objects-in-use" when they are incorporated into the local practice of a stakeholder community (Levina and Vaast 2005). A specific boundary object may therefore be used by two or more different communities of practice (see Abraham (2013) for examples).

Abraham (2013) identifies an initial set of boundary object properties based on a literature review. The identified properties can be classified into two groups: *object properties* that concern the construction of an object, and *management properties* that describe the way an object is used and managed in an organization. Depending on the type of knowledge boundary to be crossed, different properties may be required (Carlile 2004).

The object properties are described as follows. For a detailed description, see (Abraham 2013):

Modularity enables communities to attend to specific areas of a boundary object independently from each other, such as attending to individual portions of an ERP system.

Abstraction serves the interests of all involved communities by providing a common reference point on a high level of abstraction. Local contingencies are eliminated from high-level views to highlight the commonalities.

Concreteness addresses specific problems relevant to specific communities. Communities are able to specify their concerns and express their knowledge related to the problem at hand. Thus, interpretive flexibility is provided.

Shared syntax provides a common schema of information elements, so that local use of information objects is uniform across communities.

Malleability entails that boundary objects are jointly transformable to support the detection of dependencies and the negotiation of solutions.

Visualization entails that boundary objects do not rely on verbal definitions, but possess a graphical or physical representation (e.g., a drawing or a prototype).

Annotation enriches boundary objects with additional information by individual communities in order to provide context for local use.

The management properties are described as follows. For more details, see (Abraham 2013):

Versioning traces changes to boundary objects, along with their rationale. Additional context is provided by reconstructing the chronological evolution of the boundary object.

Accessibility includes informing interested communities about the boundary object using appropriate communication channels and other measures aimed at helping communities to use the boundary object, such as trainings. As a result, the boundary object is easier to access for the involved communities.

Up-to-dateness includes timely communication of changes to the involved communities as well as responsibilities and processes for updating the boundary object.

Stability implies that the structure and underlying information objects of a boundary object remain stable over time. Despite different local uses and annotations, boundary objects provide a stable reference frame: While changes at the periphery are possible, the core of the boundary object remains stable and recognizable.

Participation means that relevant communities should be involved in the creation and maintenance of the boundary object, and that users should also include top management.

## C.3 Research approach

To address our research question we conducted a series of semi-structured qualitative expert interviews. We chose this approach because it provides in-depth insights into complex phenomena (Ghauri and Grønhaug 2010) such as communication defects in EA-driven enterprise transformations. Semi-structured interviews are focused on the research problem while at the same time allowing for exploration of the field of research (Flick 2009). This combination allowed us to focus on our research problem and be open to new ideas.

We used the snowball sampling technique. According to Miles and Huberman (1994) snowball sampling is useful to identify experts that have a lot of experience concerning the phenomenon studied. In total, we interviewed twelve experts. We stopped collecting data when we did not gain any new insights into our research problem, i.e., at the point of theoretical saturation (Eisenhardt 1989). Table 14 gives an overview of the interviewees.

Each interview took between 60 and 90 minutes. All the interviews were recorded and transcribed. We started the interview analysis with open coding following Flick (2009). That is, the first codes were linked closely to the transcripts. For the specific purpose of this paper, however, we analyzed the interviews in a second step with regard to the three types of knowledge boundaries and with regard to the use of boundary objects. Furthermore, we specifically looked into the role of the enterprise architects in the context of mitigating communication defects. Eventually, this helped us to extract, combine and interpret the relevant data from the interviews.

The coded data was analyzed in two steps: (1) Based on the interviews we classified the specific communication defects presented in section 2 according to Carlile's knowledge boundaries (Carlile 2004). The mapping of the six specific communication defects to the knowledge-boundary types is presented in section 4.1. (2) As a second step we analyzed the interviews with regard to the boundary object properties. We added those properties we could find support for in our interviews to the map created in step one. The mapping of the properties to the communication defects and the knowledge boundaries is described in sections 4.2 and 4.3.

*Table 14: Characteristics of the experts*

| Expert | Position | Industry | Works in | Nationality |
|---|---|---|---|---|
| #1 | Enterprise architect | Consulting | Australia | The Netherlands |
| #2 | Enterprise architect | Energy | The Netherlands | The Netherlands |
| #3 | Enterprise architect | Insurance | USA | USA |
| #4; #7-9 | Enterprise architect | Consulting | The Netherlands | The Netherlands |
| #5 | Enterprise architect | Consulting | USA | USA |
| #6 | Enterprise architect | Public sector | The Netherlands | The Netherlands |
| #10 | Management consultant | Consulting | The Netherlands | The Netherlands |
| #11 | Enterprise architect | Banking | Luxembourg | France |
| #12 | Enterprise architect | Consulting | The Netherlands | The Netherlands |

## C.4 Results

### C.4.1 Mapping communication defects to knowledge boundaries

In our analysis we focused on the category 'inappropriate communication' (Niemietz et al. 2013), because the other two categories ('lack of communication' and 'over-communication') refer to the amount of communication, which is unlikely to be addressed by EA models and therefore is not relevant to the purpose of this paper. To answer the question to what extent EA models can be used as boundary objects to mitigate inappropriate communication, we first map the specific communication defects according to Carlile (2004) in syntactic, semantic and pragmatic knowledge boundaries (Table 15).

*Inappropriate communication means*. Communication means, such as face-to-face communication, newsletters or intranets, are used to transfer knowledge. However, our interview results indicate that the appropriateness of one and the same communication mean depends on the purpose of the communication and on the target group. For instance, one enterprise architect contrasted IT-oriented people and business-oriented people: While email, social-media channels or internet would work well for IT people, for business people he would rather arrange meetings where they could discuss things and have coffee together. The use of inappropriate communication means, e.g. using email threads towards business people, disturbs the transfer of knowledge and can thus be interpreted as an information-processing or *syntactic boundary*.

*Inappropriate communication style.* Different stakeholder communities have different preferences regarding the communication style. "*When you talk to architects you have to be sure that there is one mistake in the picture, so they really can find the mistake in the picture. And they are proud they found that mistake. […] An architect thinks that's funny. That's the way they look at things. […] When you are introducing a mistake in the picture when you are talking to managers, they are becoming insecure. They are not sure anymore that you really know what you are doing. […] You have to fit your communication with the one you are talking to*" [expert #6]. This quote shows that the inclusion of a mistake in a picture has a different meaning for enterprise architects than it has for management. Therefore, we classify this defect as *semantic boundary*.

*No shared frame of reference.* Niemietz et al. (2013) illustrate that different stakeholder communities can have different frames of reference. They distinguish two levels of differences: the level of vocabulary and the level of understanding. If two communities differ in terms of vocabulary, the *boundary is syntactic*. If they use the same terminology but have a different understanding of it, there is a *semantic boundary* between them.

*Communication against the transformation.* Stakeholders who do not want the transformation to happen sometimes try to stop it by communicating against it. As this communication defect is based on conflicting interests and can be understood as political intervention, we classify it as a *pragmatic boundary*.

*Implicit and explicit communication not aligned.* This communication defect concerns inconsistencies between what is communicated through explicit statements and what is communicated implicitly through actions, symbols, etcetera (Niemietz et al. 2013). If, for example, senior management explicitly declares the increase of service quality as a main goal and at the same time introduces the reduction of costs as a new KPI, the explicit and implicit communication is not aligned. This can be interpreted as a difference in interest and therefore as a *pragmatic boundary*.

*Dishonest communication.* An example for dishonest communication that was mentioned during our interviews is not telling the negative consequences of a transformation initiative. Such a communication defect is politically motivated and can therefore be labeled as *pragmatic boundary*.

*Table 15: Communication defects and knowledge boundaries*

| Communication defect | Syntactic boundary | Semantic boundary | Pragmatic boundary |
|---|---|---|---|
| Inappropriate means of communication | x | | |
| Inappropriate communication style | | x | |
| No shared frame of reference | x | x | |
| Communication against the transformation | | | x |
| Implicit and explicit communication not aligned | | | x |
| Dishonest communication | | | x |

### C.4.2 Mapping object properties to knowledge boundaries and communication defects

After mapping specific communication defects to knowledge boundaries we analyzed the interviews regarding boundary object properties. Table 16 shows which properties were supported as being relevant for bridging certain knowledge boundaries and for mitigating specific communication defects. When assessing the mapping of properties to knowledge boundaries it must be considered that crossing knowledge boundaries is a cumulative process. To cross a pragmatic boundary for example, semantic and syntactic boundaries must be crossed before. However, to not clutter the table only the properties that have been explicitly identified as relevant to a specific defect or boundary are marked (i.e., no accumulation effects are represented in the table). In our analysis we distinguish object properties (this section) and management properties (section 4.3). The latter are marked grey in Table 16.

*Table 16: Boundary object properties, knowledge boundaries and communication defects*

| Communication defect | Syntactic boundary | Semantic boundary | Pragmatic boundary |
|---|---|---|---|
| Inappropriate means of communication | Accessibility | | |
| Inappropriate communication style | | Visualization | |
| No shared frame of reference | Shared syntax | Modularity, Abstraction/ Concreteness, Visualization, Stability | |
| Communication against the transformation | | | Participation |
| Implicit and explicit communication not aligned | | | |
| Dishonest communication | | | Up-to-dateness |

*Shared syntax.* If an EA model uses vocabulary that is common among different stakeholder groups in an organization, shared syntax and a common frame of reference can be achieved. This can, for example, be accomplished by agreeing on the terminology of one stakeholder community ("*you need to talk purely in business terms*" [expert #1]) and capturing this in an information model. Another possibility is to use external standards (if this is compatible with the organizational culture). One interviewee described an engineering-driven organization that was very keen on complying with ISO naming standards in their models. A communication defect resulting from a lack of a shared frame of reference due to different vocabulary can thus be solved, which means that shared syntax is primarily associated with a syntactic boundary.

*Modularity.* By providing different views of an EA model, where each view captures the concerns of a particular stakeholder community, these communities can focus on different parts of an EA model. Moreover, stakeholder communities can hide parts of an overall model they are not interested in. Since views enable each community to explicate their understanding, perspectives can be compared and differences detected. One interviewee explained that views enabled him to communicate architecture "*in* *terms that can be understood by other stakeholders"* [expert #7]. A communication defect due to a lack of a shared frame of reference caused by different interpretations can be overcome by using an EA model and providing appropriate views to the involved communities. This property is therefore linked to a semantic knowledge boundary.

*Abstraction/concreteness.* Our informants stated that stakeholders needed to be able to overlook a transformation project at an early phase to "*really understand what this change means"* [expert #6]. As a specific example, the ArchiMate layer diagram was mentioned as being helpful in linking business processes at a high level to the organizational structure, and eventually to the technology layer. For an EA model as a boundary object this implies that architects should be able to provide a short and concise overview that will necessarily be at a high level of abstraction. Some informants mentioned a one-page overview, i.e., an architectural model showing the envisioned transformation in a very concise way, as an important success factor.

In an early phase of a transformation, a high level of abstraction is important for communicating the transformation goal to stakeholders. However, as a transformation goes on and concrete decision alternatives become available, more concrete models are becoming increasingly useful. Since EA models with an appropriate balance between abstraction and concreteness can help communities in quickly assessing differences in interpretation, they contribute to a shared frame of reference by providing common meanings. Therefore, abstraction/concreteness are associated with semantic boundaries.

*Visualization.* The interviewees argued for visually appealing, graphical representations of architectural models. From the majority of our interviews, it emerged that a visual representation is more highly valued than plain text. Cognitively effective models can address communication defects caused by inappropriate means of communication, as well as those caused by a lack of a shared frame of reference. Visualization is therefore particularly useful for crossing semantic boundaries. However, one interviewee reported on an organization that preferred written text over graphics. This shows that the usefulness of visualization depends to a certain degree on the communities' preferences.

Our interviews did not support the properties of *malleability* and *annotation*.

### C.4.3 Management properties and the role of the enterprise architects

We have shown that most of the object properties discussed in section 2.2 are supported by empirical data. However, we also must consider *management properties* of boundary objects (section 2.2). The idea of management properties is supported by our interviewees who point out that, next to the design of appropriate EA models, their management by the enterprise architects is particularly important. In the interviews we found evidence for four of the five management properties.

*Stability/up-to-dateness.* According to the experts an enterprise architect has to deal with the trade-off between stability and up-to-dateness of an EA model. They indicated that the more unstable a model was, i.e., the higher the update frequency, the more they had to invest in communication to maintain a shared understanding among the stakeholders. Conversely, a high degree of stability of a model can lead to a structure that is well-recognized among diverse communities, and thus contributes to establishing a common meaning. Therefore, stability contributes to crossing semantic boundaries. However, EA models also have to be updated regularly "*because the world is changing, your enterprise is changing, people are changing*" [expert #9]. If an enterprise architect does not update an EA model although s/he knows that something relevant has changed, this can be interpreted as dishonest communication. Hence, up-to-dateness can help in crossing a pragmatic boundary.

*Accessibility.* According to our interviews making an EA model accessible does not only include putting it on a server that everyone can access. Depending on their preferences regarding the means of communication people would or would not access that server (section 4.1). One architect illustrated his way to make his one-page overview of a future architecture accessible: "*So using that paper everywhere you go and put it on the table, leave it on the walls is helping you because everyone knows where his part is on the project*" [expert #8]. This quote shows that accessibility can also be reached by personal interaction. By ensuring that everyone receives the information accessibility helps crossing syntactic boundaries. Moreover, if an EA model is made accessible by personal interaction of the architect, this can also help crossing semantic boundaries because the architect can directly explain or translate the model to the respective audience: "*I was naïve enough in the beginning to think that if it was written down and if you have models then people would understand what was written down and they would understand those models. And then everybody would be on the same* *page. But that turns out not to be the case. So it's a lot of personal interaction with people*" [expert #1].

*Participation.* The interviewees mentioned participation as an essential condition for the acceptance of an EA model. "*People need to know about it, but also need to have the feeling that their voice is heard and that their concerns are included in the architecture*" [expert #7]. If a stakeholder has participated in creating an EA model for the transformation, s/he is more likely to support the transformation. Thus, the probability for communication against the transformation is decreased. Participation in the process of creating and maintaining an EA model of a future architecture by a broad number of stakeholders can therefore help in bridging pragmatic boundaries. However, developing common interests among different stakeholder communities requires strong personal involvement of the architects. Virtually all of our interviewees stressed the importance of conducting workshops in order to engage stakeholders instead of preparing a target architecture themselves and presenting the finished result.

However, the experts also pointed out that, if the architect does not intervene, letting different stakeholders participate in creating an EA model and conducting joint workshops often results in communication defects. The interviewees emphasized the architects' role as a translator or mediator between the different groups: "*And I invite people to do not judge or make assumptions but listen what other people have to say before they reply. So don't have their answers ready and just wait for the right keyword to jump in. Let other people speak. But I will always take the role of summarizer only. So whenever someone has spoken I will then give a summary. […] So I will repeat what was said and use different words so that the different people will be able to pick it up*" [expert #1].

*Versioning.* We did not find support for this property in our interviews.

We have illustrated that solely having EA models whose construction adheres to certain properties may not be sufficient to mitigate certain communication defects. The examples above show that to implement the management properties for EA models, the architect's personal interaction is needed. They have to make sure their models are recognized and understood by the relevant stakeholders. Furthermore, architects act as translators between different stakeholder communities. The property 'participation' expresses the need for also engaging stakeholders when creating EA models. In summary, the involvement of enterprise architects is needed to cross all three boundary types (Table 16).

Furthermore, in the interviews, no management property was directly linked to the defect 'explicit and implicit communication not aligned'. However, we argue that the combination of stakeholder engagement and personal interaction of the architects may also help to mitigate this defect. Through participation stakeholders express and document their concerns explicitly. If later the implicit communication contradicts those explicitly stated goals, the architects can point that out through personal interaction.

Finally, the interview analysis shows that pragmatic boundaries cannot be bridged by EA models and architects alone. However, an EA model that has invited participation from many stakeholders may help convey a de-politicized perspective that is considered more objective. When an EA model is recognized among stakeholder communities as providing a neutral, commonly agreed-upon perspective (instead of being perceived as disproportionately representing a single community's perspective), it will be harder (albeit not impossible) for politically-motivated stakeholders to push their own agenda and communicate against the transformation.

## C.5 Discussion

Our data suggest that EA models as boundary objects are particularly helpful for crossing semantic boundaries, especially when helping to identify differences in interpretation and thereby preventing communication defects caused by the lack of a shared frame of reference. For addressing semantic boundaries, visualization, abstraction, and modularity emerged as the most important properties of EA models. These properties help different stakeholder communities to identify misunderstandings and re-align their interpretations towards a shared understanding. To maintain shared understanding and a common frame of reference, mock-ups of user-interface screens or roadmaps have been named by interviewees as valuable tools supporting EA models. Particularly roadmaps received attention for highlighting dependencies between the actions of various stakeholder communities, and also for showing individual stakeholders when and to what degree their areas of concern will be affected by a transformation. However, also at a semantic boundary, the involvement of the architect is required to ensure that these boundary objects are actually used and that stakeholder concerns are adequately reflected.

Overall, the harder a communication defect is to fix, the more involvement of the architect is required: While an established and well-communicated information model, crossing a syntactic boundary, functions largely without the architect's intervention, overcoming pragmatic boundaries requires strong personal and time-consuming involvement, e.g., by conducting face-to-face meetings, negotiations, and workshops.

To cross pragmatic boundaries and address communication defects such as dishonest communication, or communication against the transformation, requires both EA models that are trusted for the accuracy of their content, and skilled architects that are trusted for the way they are managing and using these models. Especially when pragmatic boundaries are encountered, the architect needs to perform a role as a 'boundary spanner', i.e., s/he needs to invest significant effort in upholding communication between diverse stakeholder communities.

Levina and Vaast (2005) identified three conditions effective boundary spanners need to meet: (1) Boundary spanners need to have sufficient knowledge and understanding of each of the fields they are about to span to be perceived as legitimate and competent. For architects, this means that they need to have an understanding of both business and technological terms to be respected as competent by both business-unit and IT-unit members and to be able to fulfill their translator role. (2) Boundary spanners need to be considered legitimate negotiators of their own field. For architects, this means that they need to be perceived as authorized to make architectural decisions, to give dependable advice. An example would be granting exceptions from architectural principles. (3) Boundary spanners need to possess the required communication and negotiation skills associated with this role. And they need to be willing to perform a boundary spanning role between two different fields instead of becoming functional experts in one field alone. For architects, this brings the risk that they are considered as being caught in the middle between the business and IT domain, without being seen as legitimate and competent members of either one. To mitigate this risk and support the boundary-spanning function, skilled architects need to be able to rely on the proper tools, one of which are boundary objects.

## C.6 Conclusion

In this paper, we have analyzed the knowledge boundaries lying beneath various communication defects. In a second step we have shown how EA models acting as boundary objects can be used to overcome these communication defects. We conclude that EA models are most useful for crossing semantic boundaries when they possess the object properties abstraction, modularity, and visualization, whereas for communication defects residing at pragmatic boundaries enterprise architects are required to perform a boundary-spanning function.

Although this inquiry builds on both theoretical considerations and empirical data, the findings are still preliminary. Further in-depth studies are necessary to understand the construction of those (few) EA models that work as boundary objects, and the context of their use. Also, the EA function is implemented differently across organizations, e.g., with respect to governance structures. Thus, the architect's role, organizational position, tasks and responsibilities, as well as his/her interface with specific stakeholder communities (e.g., project managers or HR managers) needs to be further analyzed. Finally, more work needs to be done regarding the theoretical framing of communication (defects) in EA-driven enterprise transformations. This will help in classifying specific situations as being communication defects or not and thus in identifying those situations where EA models are likely to work as boundary objects.

Summarizing, this inquiry is a step to eventually derive design principles for EA model construction and management that are particularly suitable for overcoming communication defects.

*Acknowledgement*

This work has been funded by the Swiss National Science Foundation (SNSF) and the Fonds National de la Recherche (FNR) Luxembourg.

# Paper D – Crossing the line: overcoming knowledge boundaries in enterprise transformation

*Table 17: Bibliographical metadata on Paper D*

| Attribute | Value |
|---|---|
| Title | Crossing the line: overcoming knowledge boundaries in enterprise transformation |
| Author(s) | Abraham, Ralf; Aier, Stephan; Winter, Robert<br>University of St. Gallen, Müller-Friedberg-Strasse 8, 9000 St. Gallen, Switzerland<br>ralf.abraham@unisg.ch, stephan.aier@unisg.ch, robert.winter@unisg.ch |
| Selected approach for order of authors | Sequence determines credit |
| Publication outlet | Business & Information Systems Engineering |
| Publication type | Journal paper |
| Publication year | forthcoming |
| Rating (Jourqual 2.1) | B |
| Publication status | Accepted for publication |

*Abstract*

Enterprise transformations are fundamental changes in an organization. Such changes typically affect different stakeholder groups (e.g., program managers, business managers) that exhibit a significant diversity regarding their members' knowledge, goals, and underlying assumptions. Yet, creating shared understanding among diverse stakeholder groups in transformations is a main antecedent for success.

In this paper, we analyze which properties of enterprise architecture models contribute to syntactic, semantic, and pragmatic capacities and thereby help to create shared understanding among stakeholder groups involved in enterprise transformation. We assess the differences among stakeholder groups through the lens of knowledge boundaries, and enterprise architecture models through the lens of boundary objects. We develop and empirically test a research model that describes which boundary object properties are required to overcome three progressively complex knowledge boundaries—syntactic, semantic, and pragmatic.

Our findings show which boundary object properties contribute to a respective capacity needed to overcome each of the three knowledge boundaries. Specifically, we find that for (1) a syntactic capacity, concrete and modular EA models are helpful; (2) a semantic capacity, visual EA model properties are relevant, and (3) a pragmatic capacity, broad stakeholder participation is conductive.

*Keywords*

Boundary objects, Enterprise architecture, Enterprise transformation, Knowledge boundaries, Structural equation modeling

## D.1 Introduction

Enterprises face an increasing pressure to undergo fundamental change, in other words to transform themselves (Purchase et al. 2011; Rouse 2005b). The causes for such transformation efforts range from internal events like business- or IT-driven initiatives to external events such as the emergence of new technologies or changing regulatory requirements. For this paper, we follow the definition of Rouse (2005b) and refer to changes that fundamentally alter an enterprise's relationship with one of its key constituencies (such as employees, suppliers, customers, or investors) as *"enterprise transformation"* (ET).

ET affects—in contrast to routine business or small-scale, local change—multiple parts of the organization (Rouse 2005a). The diversity of the affected organizational domains is mirrored in the diversity of the affected stakeholder groups: ET typically is a collaborative endeavor of diverse stakeholders (concerning their knowledge, values, and goals) such as enterprise architects, project/program/portfolio managers, or managers of the affected business units. The need for collaboration among diverse organizational communities is well-recognized in literature (Carlile 2004; Karsten et al. 2001; Nicolini et al. 2012). To enable and support collaborative efforts during ET, a key success factor is to establish a shared understanding on the current situation, transformation goals, and each other's plans and objectives (Bisel and Barge 2010; Ford and Ford 1995; Stensaker et al. 2008).

To foster shared understanding among stakeholder groups during an ET, one of the major means of communication are models (Frank et al. 2014). To match the diversity of perspectives of stakeholder groups involved in an ET, *enterprise architecture* (EA) models appear particularly promising: EA models cover dependencies across partial views of an enterprise (e.g., business, technology), and are at a higher level of abstraction than models concerned with partial views. They are of interest to many diverse stakeholder groups because of the holistic overview they provide (Tamm et al. 2011; van der Raadt et al. 2010).

To better understand how communication can be supported via EA models the concept of *boundary objects* is used. Boundary objects provide interfaces among different communities of practice (e.g., IT managers and business managers). The boundary object concept has been used in IS literature to analyze the role of IT artifacts, objects, and models for communication among communities of practice (Doolin and McLeod 2012; Karsten et al. 2001; Levina and Vaast 2005; Pawlowski and Robey 2004). The boundary object concept allows to simultaneously regard material properties of EA models and the social context of their use (Doolin and McLeod 2012; Levina and Vaast 2005). Different communities of practice will perceive the quality of a boundary object differently. Therefore, we do not assess specific EA models or model types based on existing quality criteria for conceptual models (e.g., Frank 2014; Krogstie et al. 2006; Moody 2005; Nelson et al. 2012). Instead, we investigate (1) which properties of a boundary object contribute to (2) communication among stakeholder groups that possess a certain degree of difference.

To assess the degree of difference among stakeholder groups, we use the construct of *knowledge boundaries*. The main assumption is that the differences among groups with regard to their knowledge, values, and goals are manifested in three progressively complex knowledge boundaries: syntactic (information processing), semantic (interpretation), and pragmatic (political) (Carlile 2004). To help to establish shared understanding at the respective knowledge boundary, boundary objects need to have adequate syntactic, semantic, or pragmatic capacities (Rosenkranz et al. 2014).

We formulate our research question accordingly: *What are the properties of EA models that enable syntactic, semantic, or pragmatic capacities from a boundary object perspective?* To answer this research question, we employ structural equation modeling. We identify EA model properties that have a traceable effect on certain capacities—concrete and modular EA models for a syntactic capacity, visual model properties for a semantic capacity, and models with participation from many communities for a pragmatic capacity. We also point out the limitations of EA models by showing when they need to be supplemented by human boundary spanners.

## D.2 Conceptual Foundations

### D.2.1 Boundary Objects

Boundary objects are abstract or physical artifacts that support overcoming knowledge boundaries and thus support coordination among different communities of practice by providing common ground. We adopt the definition of Rosenkranz et al. (2014), which builds on the seminal papers on boundary objects: "[b]oundary objects are any 'artifacts, documents, terms, concepts, and other forms of reification around which communities of practice can organize their interconnections' (Wenger, 1998, p. 107). They are 'both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites' (Star & Griesemer, 1989, p. 393)" (Rosenkranz et al. 2014, p. 310).

### D.2.2 Enterprise Architecture Models as Boundary Objects

EA concerns the fundamental structure of an enterprise, as well as the principles guiding its evolution (ISO/IEC/IEEE 2011). EAM aims to shape and develop an EA in a planned and purposeful way, pursuing strategic enterprise goals (Simon et al. 2014) and is considered to support ET (Asfaw et al. 2009; Labusch and Winter 2013; Simon et al. 2013). Central artifact types in EAM are EA models. One benefit is their ability to offer a common frame of reference for diverse stakeholder groups by providing a high-level representation of the basic enterprise structures (Department of Defense 2012; Simon et al. 2014; The Open Group 2011).

Regarding the role of EA models in ET as a facilitator of communication, and the role of boundary objects as communication enablers, it seems promising to conceptualize EA models as boundary objects. Valorinta (2011) indeed finds that EA "possesses many of the characteristics of boundary objects" (Valorinta 2011, p. 50). The boundary object concept motivates the (subsequently confirmed) hypothesis that EA is positively related to alignment between IS and business domains. Another application of the boundary object concept to EA is presented by Pareto et al. (2010), who apply the concept to document-based communication (supplementing face-to-face communication) in particularly heterogeneous projects (defined by the "involvement of 1000 people or more" (Pareto et al. 2010, p. 407)).

Smolander et al. (2008) advocate a shift from a blueprint metaphor of architecture, towards a language metaphor. Here, the role of architecture "directly corresponds to the idea of a boundary object" (Smolander et al. 2008, p. 582). This is particularly suitable in ET, where the diversity among communities of practice increases.

The enterprise modeling and conceptual modeling literature also have contributed to describing enterprises from a holistic point. Examples include "Multi-perspective enterprise modeling (MEMO)" (Frank 2014), "enterprise ontology" (Dietz and Hoogervorst 2008), or "value modelling" (de Kinderen et al. 2012).

### D.2.3 Boundary Object Capacities and Knowledge Boundaries

The degree of difference among communities of practice in terms of knowledge, goals, and underlying assumptions can be expressed via the construct of knowledge boundaries. *"Community of practice"* is a term coined by Wenger (2000) to describe a group of people that (1) share a joint area of concern, (2) regularly interact within a set of community-specific norms and relations, and (3) possess a shared repertoire of resources such as languages, methods, tools, stories, or other communal artifacts. ET projects will typically involve multiple communities of practice (Doolin and McLeod 2012; Janssen et al. 2013).

Carlile (2004) distinguishes three types of knowledge boundaries among communities of practice that become increasingly complex to cross: syntactic, semantic, and pragmatic knowledge boundaries. Only after a way has been found to cross these boundaries, knowledge can be transferred, translated, or transformed among the involved communities of practice, resulting in shared knowledge. However, before shared knowledge between two communities of practice can be achieved via any of the three aforementioned processes, shared understanding must be established: only when a sufficient "degree of cognitive overlap and commonality in beliefs, expectations, and perceptions about a given target" (Cohen and Gibson 2003, p. 8) is created, can two communities of practice share knowledge. The key argument for shared knowledge to be "*always* based on shared understanding" (Rosenkranz et al. 2014, p. 308. emphasis in the original) is that two communities of practice need to first align their "interpretative schemes" (Giddens 1984, p. 29) when they are confronted with a novel situation (like ET). Only after these schemes have been aligned can the communities of practice begin to share knowledge and jointly build new knowledge. In Table 18, we summarize the discussion on knowledge boundaries.

*Table 18: Knowledge boundary types and associated processes of sharing knowledge (based on Rosenkranz et al. (2014))*

| Attribute | Syntactic knowledge boundary | Semantic knowledge boundary | Pragmatic knowledge boundary |
|---|---|---|---|
| Alternative name: (Knowledge) Boundary of… | Information processing | Interpretation | Politics |
| What needs to be developed to overcome knowledge boundary | Common lexicon | Common meanings | Common interests |
| Process to share knowledge after establishment of shared understanding | Knowledge transfer | Knowledge translation | Knowledge transformation |
| Boundary object capacity required | Syntactic capacity | Semantic capacity | Pragmatic capacity |
| Required capacity/capability | Capacity: Boundary objects | Capability: Boundary objects (capacity), along with boundary spanners' ability | Capability: Boundary objects (capacity), along with boundary spanners' ability |

Knowledge transfer is concerned with transmitting information from one community of practice to another. A syntactic knowledge boundary exists due to different vocabulary among communities of practice. To create shared understanding at a syntactic knowledge boundary, a common lexicon must be developed (Carlile 2004; Kotlarsky et al. 2012).

Knowledge translation is concerned with making the perspective of one community of practice intelligible to other communities. A semantic knowledge boundary exists when communities of practice attribute different meanings to concepts, and have different interpretations of concepts. (Carlile 2004; Hawkins and Rezazade M 2012). To create shared understanding at a semantic knowledge boundary, common meanings must be developed by translating and negotiating among the different meanings of the involved communities.

Knowledge transformation is concerned with altering existing knowledge structures and cognitive frames of communities of practice (Boland and Tenkasi 1995; Carlile

2004). A pragmatic knowledge boundary exists when communities of practice have different interests which affect their ability and willingness to share knowledge. To create shared understanding at a pragmatic knowledge boundary, common interests among the communities of practice must be developed via negotiation processes (Carlile 2004).

Boundary objects are helpful to establish shared understanding at any of these knowledge boundaries. The capacity of the boundary objects, along with the ability of the boundary spanners (i.e., human actors like enterprise architects, who enable communication among different communities like transformation managers or business managers) to use them accordingly, results in a capability to cross a certain knowledge boundary ("capacity x ability = capability" (Rosenkranz et al. 2014, p. 311)).

## D.3 Research Model

### D.3.1 Model Development

This paper integrates the results of a cumulative research process. In the first iteration, a structured literature survey has been conducted. 25 articles from leading journals and conferences in the information systems (IS), organizational studies, and general management domains have been analyzed (search term "boundary object*" in title and abstract). The resulting papers have then been scanned for boundary objects and their properties (Abraham 2013), resulting in an initial set of eleven boundary object properties.

*Modularity*: Communities can attend to specific areas of a boundary object independently from each other (e.g., attending to individual portions of a roadmap) (Pawlowski and Robey 2004; Star 2010).

*Abstraction*: A common reference point on a high level of abstraction is provided. Local contingencies are eliminated from high-level views to highlight the commonalities (Gasson 2006; Levina and Vaast 2005).

*Concreteness*: Specific problems relevant to specific communities are addressed. Communities are able to specify their concerns and express their knowledge related to the problem at hand (Carlile 2002; Pawlowski and Robey 2004).

*Shared syntax*: A common schema of information elements is provided, so that local use of information objects is uniform across communities (Dodgson et al. 2007; Pawlowski and Robey 2004).

*Malleability*: Objects are jointly transformable, to support the detection of dependencies and the negotiation of solutions and to provide the involved communities with immediate feedback on how their actions affect each other (Carlile 2004; Doolin and McLeod 2012).

*Visualization*: Boundary objects do not rely on verbal definitions, but possess a graphical or physical representation (e.g., a drawing or a prototype) (Boland and Tenkasi 1995; Henderson 1991).

*Annotation*: The boundary object can be enriched with additional information by individual communities in order to provide context for local use (Karsten et al. 2001; Yakura 2002).

*Versioning*: Changes to the boundary object are traced and rationales for changes are provided. Additional context can be provided by reconstructing the chronological evolution of the boundary object (Karsten et al. 2001; Mark et al. 2007).

*Accessibility*: Communities are informed about the boundary object using appropriate communication channels and other measures aimed at helping them to use the boundary object, such as trainings (Boland and Tenkasi 1995; Levina 2005).

*Up-to-dateness*: The boundary object is continuously updated, and changes are communicated in a timely fashion to the involved communities (Carlile 2002; Karsten et al. 2001).

*Stability*: The structure of a boundary object remains stable over time. While changes at the periphery are possible, the core of the boundary object remains stable and recognizable (Karsten et al. 2001; Yakura 2002).

The literature perspective has been complemented with a practitioner view by conducting a focus group. The focus group panelists (nine enterprise architects) were drawn from German and Swiss enterprises (mainly from the financial services and electric utility industries) and had several years of experience in the fields of EA, data architecture, IT architecture, or IT strategy (Abraham 2013). The focus group proposed an additional property (participation).

*Participation*: Communities are involved in the creation and maintenance of the boundary object. The boundary object should also be used by top management.

Then, an initial set of hypotheses has been constructed mapping the boundary object properties to syntactic, semantic, or pragmatic capacities. To further explore this mapping empirically, we conducted a series of expert interviews with twelve enterprise architects (a different panel than the focus group described above) (Abraham et al. 2013). Each interview took between 60 and 90 minutes. We coded the interview transcripts to identify occurrences of knowledge boundaries, the use of boundary objects, for example EA to-be models or EA roadmaps, and the role of enterprise architects as boundary spanners.

After reflecting the findings from the interviews and the feedback from the conference audience (Abraham et al. 2013), and after revisiting the literature on boundary objects and knowledge boundaries (e.g., Carlile 2004; Hawkins and Rezazade M 2012; Kotlarsky et al. 2012), we build and test our final research model.

### D.3.2 Model Description

The research model has two blocks: the boundary object properties, and the capacities they influence. Our unit of analysis is EA models as boundary objects. The level of analysis is the inter-group level (the capacity of EA models as boundary objects to overcome knowledge boundaries among different communities of practice). Figure 9 shows the research model.

The left part in the research model describes the boundary object properties as independent variables supporting one of the three capacities.

*Accessibility*. By using appropriate communication channels, members of different communities of practice can be familiarized with the boundary object. Explicating community knowledge, and making it accessible to others, helps to establish a common syntax (Boland and Tenkasi 1995; Smolander et al. 2008).

*Concreteness*. Boundary objects that provide communities of practice with a concrete reference point (e.g., boundary objects that adhere to an industry-wide defined standard) are found to be beneficial for establishing a common syntax (Barley et al. 2012; Bechky 2003).

*Modularity*. Pareto et al. (2010, p. 415) call for filtering components that remove parts of the model on demand. By allowing different communities to attend to different parts of the same boundary object, knowledge about each community's terms and syntax is transferred back and forth (Boland and Tenkasi 1995).

*Shared syntax* is frequently associated in literature (Carlile 2002; Kellogg et al. 2006) with overcoming syntactic knowledge boundaries.

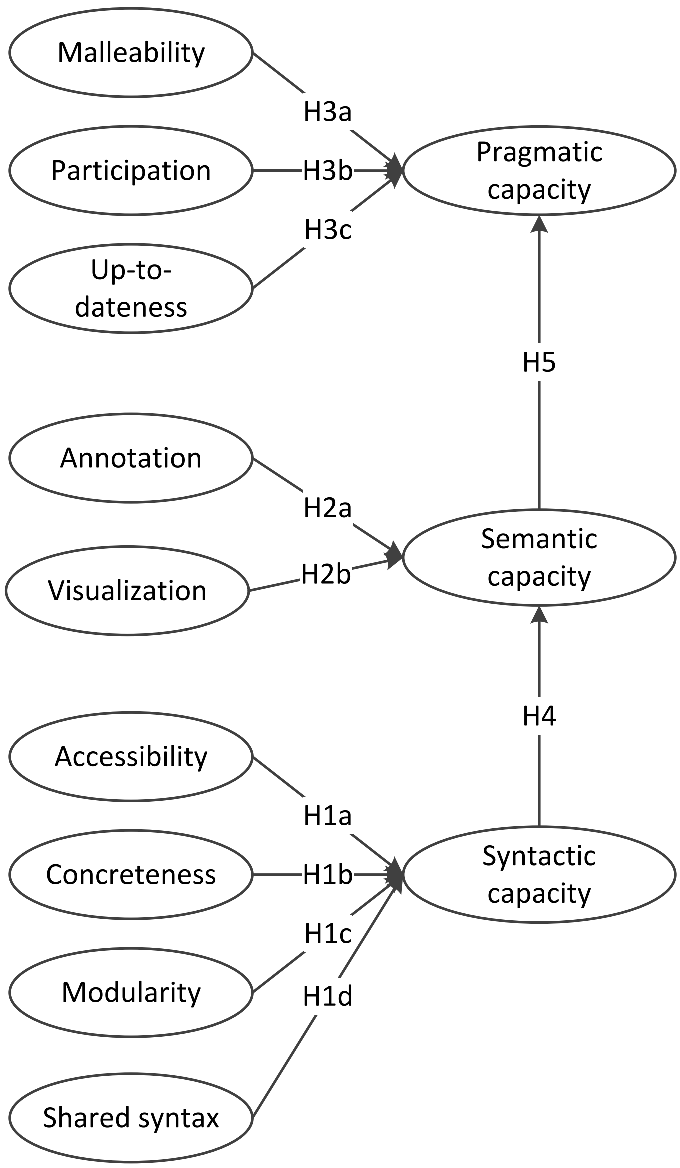


*Figure 9: Research model: boundary object properties' contribution to model capacities*

We formulate our hypotheses as follows:

- H1a: Accessibility increases the syntactic capacity of boundary objects.
- H1b: Concreteness increases the syntactic capacity of boundary objects.
- H1c: Modularity increases the syntactic capacity of boundary objects.
- H1d: Shared syntax increases the syntactic capacity of boundary objects.

*Annotation* is hypothesized to contribute to a semantic capacity, by allowing to uncover and consolidate different meanings (Pareto et al. 2010; Yakura 2002).

*Visualization.* A cognitively efficient visual notation is considered beneficial for detecting differences and dependencies in interpretation. Henderson (1991) finds that using sketches and diagrams facilitates the reading of alternative meanings among groups of engineers. Boland and Tenkasi (1995) argue that visual representations (e.g., conceptual models) support a sense-making rather than a problem-solving process. Therefore, we associate visualization with a semantic rather than a pragmatic capacity.

We formulate our hypotheses as follows:

- H2a: Annotation increases the semantic capacity of boundary objects.
- H2b: Visualization increases the semantic capacity of boundary objects.

*Malleability* is frequently mentioned in literature to support overcoming pragmatic boundaries (Carlile 2004; Doolin and McLeod 2012). A jointly transformable object helps different communities to try out solution alternatives and negotiate a common solution.

*Participation.* When communities of practice actively participate in creating, editing and maintaining the boundary object, this object is likely to enjoy higher acceptance than a “designated boundary object” (Levina and Vaast 2005). Moreover, the involved communities of practice participate in the solution negotiation process.

*Up-to-dateness*. Improvisation is a key aspect when members of different communities discuss solutions to address novel conditions. The availability of up-to-date information is an important enabler of improvisation (Vera and Crossan 2005). Conversely, when outdated information is provided, this could be interpreted as dishonest communication (Abraham et al. 2013).

We formulate our hypotheses as follows:

- H3a: Malleability increases the pragmatic capacity of boundary objects.
- H3b: Participation increases the pragmatic capacity of boundary objects.
- H3c: Up-to-dateness increases the pragmatic capacity of boundary objects.

We model concreteness as an individual construct at a syntactic knowledge boundary, since this property is hypothesized to be required for knowledge transfer. We refrain from modeling abstraction as an individual construct at the semantic knowledge boundary, but rather see it as a facet of the visualization property: Models on a high level of problem description aid knowledge translation, whereas models on a detailed level of problem description aid knowledge transfer by exposing community-specific terminology (Parsons 2003). The interlinking among different levels of problem description is part of an efficient visualization, by allowing navigation through different problem description layers (cf. Moody's (2009) design principle of complexity management).

The right part of the research model shows the three capacities that can be enabled in boundary objects—syntactic, semantic, and pragmatic capacities. By modeling an increase in complexity from a syntactic over a semantic to a pragmatic knowledge boundary, our research model is consistent with Carlile (2002; 2004) and Rosenkranz et al. (2014).

We formulate our hypotheses as follows:

- H4: An increase of the syntactic capacity of a boundary object leads to an increase of the semantic capacity.
- H5: An increase of the semantic capacity of a boundary object leads to an increase of the pragmatic capacity.

## D.4 Research Method

### D.4.1 Construct Operationalization

The necessary measurement items are derived from literature, construct definitions, and expert suggestions (MacKenzie et al. 2011). In operationalizing our constructs, we strive for reuse of existing measurement instruments which describe critical success factors and are supported by either theoretical arguments or empirical data. However, some items are directly derived from the boundary object property definitions, as there are few works in literature dealing with the exact properties of boundary objects, specifically when applied to EA models. The selection of the items and the wording of the questionnaire have been discussed over four iterations within the author team and with other colleagues (Urbach and Ahlemann 2010). The result of this discussion process is our final set of construct indicators (see Appendix A). We show where existing items could be adopted, have been newly developed, or have been dropped (when they could not be unambiguously attributed to a single construct).

### D.4.2 Sample Description

To test our hypotheses, we follow a quantitative empirical approach. We conduct a survey among EA academics and practitioners using a questionnaire. The questionnaire was distributed on six occasions in German and English language and yielded n=111 fully completed and usable questionnaires. See Appendices B and C for details on the questionnaire and the distribution occasions.

All respondents were actively engaged in EAM either professionally or academically. At all events, academics, and consultants have been instructed to answer the questionnaire from the perspective of the industry project they were most familiar with. All participants were asked to answer the questions on model use and model properties from the perspective of one particular model they considered most likely to support communication among different communities. Since we are interested in a broad coverage of the specific aspect of the models—the degree to which certain of their properties influenced certain capacities—the heterogeneity of the model instances reported in this survey is a deliberate choice (see Appendix D for an overview on the model types reported by our respondents).

Performing analyses of variance on our sample, we did not find company size, EAM, or ET experience level to have significant effects on our results, which is in line with comparable studies in IS development (Aier et al. 2011a; Aier et al. 2011b). We also no not expect geography or industry to have significant effects on our results.

The research model has been transformed into a structural equation model and tested using a partial least squares (PLS) approach (we use SmartPLS (Ringle et al. 2005), version 2.0.M3). We have used a case-wise replacement algorithm to deal with missing values. With regard to our research purpose, we favor the PLS approach. PLS has less strict distributional assumptions and is more suitable for the exploration of relationships (this is particularly relevant, since our paper is among the first to explore EA through the boundary object lens at the level of individual properties). Moreover, PLS has a lower sample size requirement. According to Chin et al. (2003), the sample size for PLS should be at least ten times the maximum number of predictor variables for a construct. In our case, this number is four (for the "syntactic capacity" construct). The resulting threshold of 40 is met by our sample size of 111. However, given the weak to moderate effect sizes in our model, our sample size is still near the minimum required sample size. The stability of the estimates has been assessed using the boot-strapping resampling procedure with 5000 resamples (Hair Jr et al. 2011, p. 145). Significances have been determined by means of two-tailed t-tests.

### D.4.3 Model Evaluation

The evaluation of the measurement model and the structural model follows the procedures outlined by Chin (2010) and Götz et al. (2010). See Appendix E for the numerical results of the model evaluation. All constructs have been measured in reflective mode. The measurement model is evaluated for the following criteria: (1) content validity, (2) indicator reliability, (3) construct reliability, (4) convergent validity, and (5) discriminant validity.

Content validity has to be ensured a priori through theoretical considerations, namely that the measurement model (qualitatively) represents the conceptual domain of the construct in question. This was done based on the previous research steps and the theoretical considerations outlined earlier.

Indicator reliability specifies which part of an indicator's variance can be explained by the underlying latent variable. The factor loadings λ should be larger than 0.7, which is the case for all indicators except MAL1 (0.69).

Construct reliability indicates how well all indicators taken together measure their respective construct. This can be measured via the composite reliability (CR) or Cronbach's alpha (CA) criterion (CA assumes equal weightings; since we do not assume equal weightings among the facets that are captured by the indicators of a construct, CR is more adequate in our case). For both CA and CR, values should be larger than 0.6. In our case, CR is always above these thresholds. CA is below this threshold for one construct (MAL at 0.44) and meets this threshold for another construct (SYN at 0.60).

Convergent validity is assessed with the average variance extracted (AVE) measure. AVE should be larger than 0.5, meaning that a greater part of the construct's variance is explained by its indicator than by the error term. In our model, this is the case. Still, for the syntactic capacity construct, both AVE and CA values are very close to the recommended minimum threshold.

Discriminant validity is about the dissimilarity of the constructs—in other words, whether the indicators load only to their own construct and not to others. According to the Fornell-Larcker-criterion (Fornell and Larcker 1981), discriminant validity is given if the square root of a latent variable's AVE is larger than the common variances (correlations) of this latent variable with any other of the model's constructs. This holds true for all our measurement constructs.

### D.4.4 Model Results

The model evaluation shows that eight out of ten hypotheses hold (see Table 19). We assess the significance of our hypotheses via a two-tailed t-test. The R-square values of 0.448, 0.331, and 0.398 for syntactic, semantic, and pragmatic capacities of boundary objects show that the associated boundary object properties account for between 33% and 45% of the variance in the capacities. While there are no universal recommendations on acceptable values for R-square (Chin 1998a; Chin 1998b), we consider this to be a reasonable value, given the complexity of our model.

*Table 19: Results of PLS path analysis*

| Hypothesis | Path description | Path coefficient, significance | t-score | Result |
|---|---|---|---|---|
| H1a | Accessibility → Syntactic capacity | 0.022 | 0.349 | Not Supported |
| H1b | Concreteness → Syntactic capacity | 0.380 | 4.162**** | Supported |
| H1c | Modularity → Syntactic capacity | 0.201 | 2.137** | Supported |
| H1d | Shared Syntax → Syntactic capacity | 0.243 | 2.491** | Supported |
| H2a | Annotation → Semantic capacity | 0.314 | 3.222*** | Supported |
| H2b | Visualization→ Semantic capacity | 0.280 | 3.698**** | Supported |
| H3a | Malleability → Pragmatic capacity | 0.246 | 3.148*** | Supported |
| H3b | Participation → Pragmatic capacity | 0.160 | 1.722* | Supported |
| H3c | Up-to-dateness → Pragmatic capacity | -0.136 | 1.561 | Not Supported |
| H4 | Syntactic capacity → Semantic capacity | 0.189 | 1.871* | Supported |
| H5 | Semantic capacity → Pragmatic capacity | 0.470 | 5.754**** | Supported |
| | | | | |
| R-square values: Syntactic capacity 0.448; Semantic capacity 0.331; Pragmatic capacity 0.398 | | | | |
| Legend: ****: α<0.001; ***: α<0.01; **: α<0.05; *: α<0.1 | | | | |

# D.5 Discussion

## D.5.1 Findings

This study contributes original insights for three reasons: First, it is one of the first studies to follow the calls in literature (Smolander et al. 2008; Valorinta 2011) to apply the boundary object concept to EAM at a specific level: our unit of analysis is an individual EA model at the inter-group level. Second, we break down the construct of boundary objects into individual properties and differentiate among three progressively complex capacities, providing design guidelines for subsequent EA model development. Third, our results shed light on the transition between the capacities of EA models, and the required abilities of enterprise architects: where are the capacities of models sufficient, and where are the abilities of enterprise architects central?

Regarding the results of the model evaluation, the properties of concreteness and visualization appear to have particular importance for syntactic and semantic capacities, being significant at the 0.001 level. For the design of boundary objects, these findings imply the importance of (1) an object that is connected to the concrete domains (i.e., universes of discourse) of the involved communities, and that (2) possesses a cognitively efficient visual notation. Interestingly, the two hypotheses that are not supported by the data are both concerned with properties that address the use and management of EA models rather than their construction—up-to-dateness and accessibility. An explanation for the lacking support of accessibility for a syntactic capacity might be that boundary objects emerge from the communities' work practices, and can only be partly pre-designed (Landry et al. 2009). The low empirical support for up-to-dateness indicates that this property does not contribute significantly to a pragmatic capacity of boundary objects. A potential explanation may be that up-to-dateness is not a capacity-enabling property, but rather an essential requirement towards any model.

The connection between a semantic and a pragmatic capacity (H5) is significant at the 0.001 level, whereas the connection between a syntactic and a semantic capacity (H4) is only significant at the 0.1 level. On the other hand, the explained variance (R-square) is highest for syntactic capacities. This is in line with the findings of Rosenkranz et al. (2014) that boundary objects are sufficient to create shared understanding at syntactic knowledge boundaries, but need to be supplemented by boundary spanners at semantic and pragmatic knowledge boundaries. Moreover, the results show that a pragmatic capacity depends strongly on the prior establishment of a semantic capacity.

### D.5.2 Limitations

Some limitations must be discussed before implications for either research or practice can be derived. First, our sample is not representative, since it focuses only on enterprise architects. While the selection of this particular community seems natural in connection with EA models, the results in this work must be interpreted accordingly. Further iterations should also consider communities like transformation managers, business managers, or program managers. In a similar vein, we did not restrict the possible answers to a specific ET scenario. However, since our primary audience are enterprise architects, we expect this group to be actively involved in ET projects, given the role of architectural support in ET.

Second, the research model requires more in-depth testing, as it presents a novel and more fine-grained perspective on EA models by breaking down the boundary objects construct into a set of EA model properties. We could only adopt few measurement items from literature, had to adapt some, and had to create new scales for several constructs.

Third, the responses collected in our survey relate to different models (see Appendix D) used by different communities of practice. The findings of this research are therefore not attributable to a specific model type used among specific communities of practice. This research must be seen as a first exploration into model properties that enable certain capacities. Further research is required to refine the results in specific model types.

Finally, we are aware that additional context factors influence shared understanding in ET. A particularly interesting context factor is the power relationships among the involved communities of practice (Barrett and Oborn 2010). In the case of a particularly lopsided power distribution, a powerful community of practice might simply force its perspective on others, instead of fostering shared understanding via boundary objects.

### D.5.3 Implications for Research and Practice

Being aware of these limitations, we nevertheless consider the boundary object lens beneficial to address the idiosyncrasies of our object of inquiry—EA models in ET. Recently published research agendas in this journal recognize the impact of stakeholder divergence on model development and call for approaches "that are suited to address the inherent divergences and the resulting frictions effectively" (Frank et al.

2014, p. 39). We consider the adherence to boundary object properties as requirements for EA model design as a contribution to meeting this challenge.

The identified properties address both material aspects of EA models (e.g., modularity), as well as the way they are embedded in a social context (e.g., participation). This integral approach is central to the boundary objects perspective of EA models: EA models become boundary objects only during their (Levina and Vaast 2005), yet this focus must not lead to neglecting the material properties of EA models. The mapping of boundary object properties to syntactic, semantic, and pragmatic capacities can provide indications to researchers which existing EA models might work as boundary objects in situations where certain capacities are required.

For researchers following a behavioristic research paradigm, the effect of boundary objects in actual ET may be observed in future studies, for example on the mutual influence of boundary objects and their application context in ET: how boundary objects shape ET (enable the transfer, translation, and transformation of knowledge), and how they are at the same time shaped by ET (i.e., how their capacities change when they get adopted or even adapted by new communities of practice). A sociomaterial perspective (Orlikowski and Scott 2008) provides a suitable lens for such investigations. For researchers following a design science research paradigm, this research is a first step towards developing design principles for boundary objects by indicating which properties to focus on when a certain capacity is desired.

For practitioners, finally, the results of this research can predict which boundary objects are effective when a certain capacity is required. Decisions could then be made to either invest in a certain capacity (e.g., invest in a syntactic capacity to free boundary spanner resources from establishing shared understanding when a comparatively easy syntactic knowledge boundary is faced), or to improve the tool set of boundary spanners at semantic or pragmatic knowledge boundaries.

## D.6 Conclusion

Motivated by the need for shared understanding among diverse communities of practice in ET, we have formulated our research question: *What are the properties of EA models that enable syntactic, semantic, or pragmatic capacities from a boundary object perspective?* We have developed a research model and tested it using PLS with a data set of 111 questionnaires collected from enterprise architects. Our findings confirm the majority of the postulated hypotheses by showing which boundary object properties are required in the presence of which knowledge boundary. We discuss implications for theory, particularly taking into account postulated research agendas for modeling IS, and formulate initial action guidelines for practitioners.

*Acknowledgement*

This work has been supported by the Swiss National Science Foundation (SNSF).

## D.7 Appendix A: Construct Indicators and Questions in the Final Survey Instrument

*Table 20: Construct Indicators and Questions in the Final Survey Instrument*

| Indicator | Description | Supporting research |
|---|---|---|
| MAL1 | The model is made physically tangible (e.g., via large-format plots). | (Barrett and Oborn 2010; Carlile 2004) |
| MAL2 | The model can be edited simultaneously by different communities. | <dropped> |
| MAL3 | Alternative problem solution options can be presented with the model. | (Barrett and Oborn 2010; Carlile 2004) |
| MAL4 | Using the model, the impact of changes can be displayed (scenarios). | <dropped> |
| PAR1 | The model is co-developed by the involved communities. | <dropped> |
| PAR2 | Model contents are approved by the involved communities. | (Schmidt and Buxmann 2011) |
| PAR3 | The model contents are regularly checked for consistency by the involved communities. | (Schmidt and Buxmann 2011) |
| PAR4 | The model is used by top management. | <dropped> |
| UTD1 | The information in the model is updated continuously. | (Schmidt and Buxmann 2011) |
| UTD2 | Updates to the model are entered quickly. | (Levina and Vaast 2005; Schmidt and Buxmann 2011) |
| UTD3 | Changes to the model are quickly communicated to the affected communities. | (Karsten et al. 2001; Schmidt and Buxmann 2011) |
| UTD4 | There are clear responsibilities for updating the model. | <dropped> |

| Indicator | Description | Supporting research |
|---|---|---|
| ANN1 | Communities may add annotations to the model. | <dropped> |
| ANN2 | Annotations to the model can be discussed via communication channels (e.g., a discussion forum). | (Karsten et al. 2001; Yakura 2002) |
| ANN3 | The model can be supplemented with community-specific information. | (Karsten et al. 2001; Yakura 2002) |
| VIS1 | The design of the model is considered beautiful. | (Moody 2009) |
| VIS2 | In the model, uniform visual techniques (e.g., colour, shape, illustrations) are used to improve understandability. | (Henderson 1991; Moody 2009) |
| VIS3 | The model can be read without using a legend. | <dropped> |
| VIS4 | Aesthetic aspects have a high priority when designing the model. | (Boland and Tenkasi 1995; Moody 2009) |
| ACC1 | The model is easily accessible to interested communities. | (Barley et al. 2012; Boland and Tenkasi 1995; Karsten et al. 2001) |
| ACC2 | Trainings for the model are offered on a regular basis. | <dropped> |
| ACC3 | The model is actively promoted in the organisation. | (Boland and Tenkasi 1995; Karsten et al. 2001) |
| ACC4 | The model is communicated to all relevant communities. | (Schmidt and Buxmann 2011) |
| CON1 | The model combines detailed views with high-level overviews. | (Bechky 2003; Levina 2005; Parsons 2003) |
| CON2 | The model is used not only across, but also within the involved communities. | (Bechky 2003; Valorinta 2011) |
| CON3 | The model provides detailed information for individual communities. | (Parsons 2003; Valorinta 2011) |
| MOD1 | The communities can restrict the model display to those areas which are relevant for them. | (Østerlund 2008; Pawlowski and Robey 2004) |
| MOD2 | Individual parts of the model can be used separately. | (Nicolini et al. 2012; Pawlowski and Robey 2004; |

| Indicator | Description | Supporting research |
|---|---|---|
| | | Winter and Butler 2011) |
| MOD3 | Parts of the model not relevant for the current task can be hidden. | (Nicolini et al. 2012; Pawlowski and Robey 2004) |
| MOD4 | Different communities can use different parts of the model independently of each other. | <dropped> |
| SHS1 | The model elements are defined with the help of domain experts. | <dropped> |
| SHS2 | There is a glossary, defining the most important model elements. | (Schmidt and Buxmann 2011) |
| SHS3 | The model takes care to use a uniform terminology. | (Schmidt and Buxmann 2011; Valorinta 2011) |
| SHS4 | The model takes care to use official terms as far as possible. | (Rehm and Goel 2013; Schmidt and Buxmann 2011; Valorinta 2011) |
| SYN1 | The model helps the communities to establish a common terminology. | <dropped> |
| SYN2 | The model uses mainly business terminology. | (Preston and Karahanna 2009) |
| SYN3 | The model uses "IT Jargon". | (Preston and Karahanna 2009) |
| SYN4 | The model helps the communities to quickly access relevant information. | (Kotlarsky et al. 2012) |
| SEM1 | The model helps the communities to uncover dependencies between their activities. | (Carlile 2004; Nicolini et al. 2012) |
| SEM2 | The model helps the communities to identify misunderstandings. | (Kotlarsky et al. 2012) |
| SEM3 | The model helps the communities to uncover differences in understanding. | (Kotlarsky et al. 2012) |
| SEM4 | The model helps the communities to uncover conflicting goals. | <dropped> |
| PRA1 | The model helps the communities to negotiate solution alternatives. | (Kotlarsky et al. 2012) |
| PRA2 | The model helps the communities to develop a shared understanding on pro- | <dropped> |

| Indicator | Description | Supporting research |
|---|---|---|
| | ject goals. | |
| PRA3 | The model helps the communities to build shared knowledge. | (Carlile 2004) |
| PRA4 | The model helps the communities to agree on a solution when multiple alternatives are available. | (Kotlarsky et al. 2009) |
| Indicators | | |
| MAL: Malleability | VIS: Visualization | SHS: Shared syntax |
| PAR: Participation | ACC: Accessibility | SYN: Syntactic capacity |
| UTD: Up-to-dateness | CON: Consistency | SEM: Semantic capacity |
| ANN: Annotation | MOD: Modularity | PRA: Pragmatic capacity |
| Supporting research | | |
| <dropped> | Item dropped based on the actual dataset | |
| <Source/s> | Item newly developed, informed by mentioned sources | |
| <Source/s> | Existing item adapted from mentioned source | |

## D.8 Appendix B: Questionnaire

### D.8.1 Introductory remarks

When answering the subsequent questions: Please consider that model which is most likely to work as a communication device between different communities (e.g., Business Units, IT, HR, Controlling…) in the organisation you are describing.

(1) Which model are you considering?

(2) Which communities are using this model as a communication device?

### D.8.2 Areas of model use

Please indicate the degree of support for the following statements regarding the model you are describing (Scale: (1) not at all; (2) hardly; (3) neutral; (4) mostly; (5) completely).

(1) The model helps the communities to establish a common terminology.
(2) The model uses mainly business terminology.
(3) The model uses "IT Jargon".
(4) The model helps the communities to quickly access relevant information.
(5) The model helps the communities to uncover dependencies between their activities.
(6) The model helps the communities to identify misunderstandings.
(7) The model helps the communities to uncover differences in understanding.
(8) The model helps the communities to uncover conflicting goals.
(9) The model helps the communities to negotiate solution alternatives.
(10) The model helps the communities to develop a shared understanding on project goals.
(11) The model helps the communities to build shared knowledge.
(12) The model helps the communities to agree on a solution when multiple alternatives are available.
(13) The model is part of standard presentations.
(14) The model is used in project documentations.
(15) The model is regularly shown in meetings.
(16) The model is used frequently (5=daily; 4=weekly; 3=monthly; 2=three-monthly; 1=yearly).

### D.8.3 Communication between the communities

Please indicate the degree of support for the following statements regarding the communities you are describing (Scale: (1) not at all; (2) hardly; (3) neutral; (4) mostly; (5) completely).

(1) The communities appreciate their mutual, interdisciplinary knowledge.
(2) The communities take each other's points of view into account.
(3) The communities try to broaden their horizon with the other communities' knowledge.
(4) The communities consider each other's perspectives.
(5) The communities have a shared understanding regarding their task in the organisation.
(6) The communities know their respective contribution to the organisation's competitiveness.
(7) The communities have a shared understanding of their respective plans.

(8) The communities have a shared understanding of their respective goals.
(9) The communities have a shared understanding of their respective challenges.

### D.8.4 Design and management of the model

Please indicate the degree of support for the following statements regarding the model you are describing (Scale: (1) not at all; (2) hardly; (3) neutral; (4) mostly; (5) completely).

(1) The communities can restrict the model display to those areas which are relevant for them.
(2) Individual parts of the model can be used separately.
(3) Parts of the model not relevant for the current task can be hidden.
(4) Different communities can use different parts of the model independently of each other.
(5) The model provides a common reference point for different communities.
(6) The model combines detailed views with high-level overviews.
(7) The model is restricted to the most important information ("80-20-rule").
(8) The model is used not only across, but also within the involved communities.
(9) The model provides detailed information for individual communities.
(10) The model shows dependencies between the areas of interest of the individual communities.
(11) The model elements are defined with the help of domain experts.
(12) There is a glossary, defining the most important model elements.
(13) The model takes care to use a uniform terminology.
(14) The model takes care to use official terms as far as possible.
(15) The model is made physically tangible (e.g., via large-format plots).
(16) The model can be edited simultaneously by different communities.
(17) Alternative problem solution options can be presented with the model.
(18) Using the model, the impact of changes can be displayed (scenarios).
(19) The design of the model is considered beautiful.
(20) In the model, uniform visual techniques (e.g., colour, shape, illustrations) are used to improve understand-ability.
(21) The model can be read without using a legend.
(22) Aesthetic aspects have a high priority when designing the model.
(23) Communities may add annotations to the model.

(24) Annotations to the model can be discussed via communication channels (e.g., a discussion forum).
(25) The model can be supplemented with community-specific information.
(26) A change history for the model is recorded.
(27) Changes to the model are controlled via a release management process.
(28) Change requests to the model are collected and lead, after agreement, to a new release.
(29) The model is easily accessible to interested communities.
(30) Trainings for the model are offered on a regular basis.
(31) The model is actively promoted in the organisation.
(32) The model is communicated to all relevant communities.
(33) The information in the model is updated continuously.
(34) Updates to the model are entered quickly.
(35) Changes to the model are quickly communicated to the affected communities.
(36) There are clear responsibilities for updating the model.
(37) The model has reached a high degree of stability.
(38) The model changes seldom. Information is still up-to-date in the near future.
(39) There are no parallel model versions in circulation.
(40) The model is co-developed by the involved communities.
(41) Model contents are approved by the involved communities.
(42) The model contents are regularly checked for consistency by the involved communities.
(43) The model is used by top management.

## D.9 Appendix C: Distribution Events and Sample Description

### D.9.1 Distribution Events

*Table 21: Distribution Events*

| Event | Date, Location, Language | Audience | n | n/N* |
|---|---|---|---|---|
| Practitioner event | February 2013, Switzerland, German | EA practitioners | 66 | 67% |
| Practitioner event | February 2013, Switzerland, German | EA practitioners | 5 | 38% |

| Event | Date, Location, Language | Audience | n | n/N* |
|---|---|---|---|---|
| EA Seminar | October 2013, Finland, English | EA researchers, practitioners | 16 | 59% |
| EA groups in online social network (XING) | December 2013 to February 2014, <Online>, German | EA researchers, practitioners | 8 | n/a |
| EA groups in online social network (LinkedIn) | December 2013 to February 2014, <Online>, English | EA researchers, practitioners | 10 | n/a |
| IS Conference | January 2014 to February 2014, <Online>, English/German | EA researchers | 6 | 21% |
| Total | | | 111 | n/a |
| *: Response rate (*n* questionnaires returned out of *N* questionnaires distributed) | | | | |

### D.9.2 Sample Description

*Table 22: Company size*

| Item | Percentage |
|---|---|
| Very large companies (5,000 employees and more) | 35% |
| Large companies (1,000–4,999 employees) | 21% |
| Medium large companies (250–999 employees) | 20% |
| Medium sized or small companies (249 employees or less) | 14% |

*Table 23: EAM existence*

| Item | Percentage |
|---|---|
| More than 5 years | 33% |
| 3–5 years | 22% |
| 1–2 years | 15% |
| less than 1 year | 7% |
| Not at all | 13% |

*Table 24: Industries*

| Item | Percentage |
|---|---|
| Financial services | 16% |
| Information and communication | 14% |
| Public services | 11% |
| Insurances | 9% |
| Manufacturing | 9% |
| Transport and logistics | 9% |

## D.10 Appendix D: Models and Communities of Practice

This appendix shows the consolidated answers of our respondents to the open questions on model and communities. Answers could be made as free text. Some respondents named multiple models or communities.

*Table 25: Models and Communities of Practice*

| Times mentioned | Model | Associated communities of practice |
|---|---|---|
| 17 | Capability map | IT, Business units, Top management, (internal) IT customers, Architecture board, HR, Controlling, Business transformation, IT architecture, Business architecture, Users |
| 10 | Domain models | all IT Management communities, Top management, Business unit management, Product management, Architecture, Sales support, IT, Business units, Business analysts, Software analysts, Software engineering |
| 6 | Process models | IT, Business units, Top management, IT steering committee, Business continuity management, IT Supply chain management, Strategy, Organization |
| 5 | Application landscape | IT, Business units, IT management, Portfolio management, Architecture boards, Projects, Business, architecture, Development |

| Times mentioned | Model | Associated communities of practice |
|---|---|---|
| 5 | EAM | IT, Business units |
| 5 | Zoning plan | Top management, IT management, business process management, developers, Business units |
| 4 | Business object model | IT, Business units |
| 4 | Business process modeling notation | IT, Business units, Controlling, Quality managememt |
| 4 | Requirements list | IT, Business units |
| 4 | Use cases | Architecture management, Project management, IT, Business units |
| 3 | Business architecture | Development, Project managers, Business units, IT |
| 3 | TOGAF | IT, Business units |
| 2 | Application architecture | Project managers, Business units, Software architecture, IT development, IT operations |
| 2 | Architecture landscape | all communities |
| 2 | Data models | Process sponsors, process owners, Controlling, Risk management, Business architecture, IT |
| 2 | Decision tree | IT, Business units, Suppliers, Enterprise architecture, Project management, Application operators, Business architecture |
| 2 | Meetings | IT architects, Application owner, IT management, Business architecture, Solution architecture, Business analysts, Top management |
| 2 | Operations model | Sales, Project managers, IT, IT systems/service users, internal IT service department |
| 2 | Process landscape | IT, Business units, vendors, HR |
| 2 | Roadmap | IT, Business units |
| 2 | Service model | IT, Business units, Risk management, Process analysts, Strategic planning |
| 2 | Target architecture | IT, Business units |

| Times mentioned | Model | Associated communities of practice |
|---|---|---|
| 1 | 4EM | IT Workers, IT Managers (Business side), selected business units |
| 1 | Action items | IT, Business units |
| 1 | ArchiMate | IT, Business units |
| 1 | Architecture framework | Business alignment |
| 1 | Architecture models | all communities |
| 1 | Boards | IT, Business units |
| 1 | Budget plan | all communities |
| 1 | Business interaction model | IT, Business units |
| 1 | Business model | IT, Business units |
| 1 | Business process map | IT, Business units, Administration |
| 1 | Conceptual data model | not clearly definable |
| 1 | Decision documentation | IT |
| 1 | Enterprise business frame-work | IT, Business units |
| 1 | Financial figures sheet | Business development, planning com-munity |
| 1 | IBM CBM | Business development, planning com-munity |
| 1 | Information architecture model | Business development, System owners, Project managers (IT, Business), Soft-ware architects |
| 1 | Information model | Project management, IT |
| 1 | Interface diagrams | Project management, IT |
| 1 | Investment overview | all communities |
| 1 | IT landscape | all communities |
| 1 | IT service catalog | IT |
| 1 | IT Service management (ITIL) | IT, Business units |
| 1 | ITM Operations model | IT architecture, Business architecture, Project management, Business analysts |

| Times mentioned | Model | Associated communities of practice |
|---|---|---|
| 1 | Leadership system | Information management, IT service providers, IT governance |
| 1 | Maturity model | IT architects, Application owner, IT management, Business architecture, Solution architecture, Business analysts |
| 1 | Multi-perspective models | Business units, Project management, Architects |
| 1 | NATO Architecture Framework (NAF) | IT, Business units |
| 1 | Organization structure | <no answer> |
| 1 | Pace layering model | <no answer> |
| 1 | Planning sheet | Middle management |
| 1 | PowerPoint | Business units, HR, Controlling, Process management, IT |
| 1 | Process cluster | IT, Business units, users, vendors |
| 1 | Process map | IT, Business units |
| 1 | Project portfolio | System owners, Developers, Managers |
| 1 | Reference models | IT, Business units |
| 1 | Server deployment maps | IT, Business units, Risk management, Process analysts, Strategic planning |
| 1 | Service price list for IT outsourcing services | IT, Business units, Risk management, Process analysts, Strategic planning |
| 1 | Strategy roadmap | all communities |
| 1 | UML | IT, Business units, vendors |
| 1 | User interface models | IT, Architects, Business units |
| | | |
| Total: 130 | (some respondents mentioned multiple model types) | |

## D.11 Appendix E: Model Quality Criteria

*Table 26: Measurement Model (Survey Items, Mean Value, Standard Deviation, Factor Loading)*

| Indicator | μ | σ | λ | | Indicator | μ | σ | λ |
|---|---|---|---|---|---|---|---|---|
| MAL1 | 3.29 | 1.38 | 0.69 | | MOD1 | 3.69 | 1.04 | 0.86 |
| MAL3 | 3.02 | 1.20 | 0.89 | | MOD2 | 3.86 | 1.15 | 0.85 |
| PAR2 | 3.12 | 1.30 | 0.94 | | MOD3 | 3.64 | 1.28 | 0.86 |
| PAR3 | 2.82 | 1.30 | 0.87 | | SHS2 | 3.38 | 1.48 | 0.75 |
| UTD1 | 3.52 | 1.26 | 0.79 | | SHS3 | 3.90 | 1.03 | 0.93 |
| UTD2 | 3.26 | 1.17 | 0.86 | | SHS4 | 3.74 | 1.14 | 0.81 |
| UTD3 | 3.27 | 1.17 | 0.91 | | SYN2 | 3.58 | 1.16 | 0.76 |
| ANN2 | 2.59 | 1.36 | 0.93 | | SYN3 | 3.49 | 0.98 | 0.73 |
| ANN3 | 3.02 | 1.22 | 0.86 | | SYN4 | 3.65 | 1.01 | 0.73 |
| VIS1 | 2.86 | 1.35 | 0.83 | | SEM1 | 3.74 | 1.02 | 0.69 |
| VIS2 | 3.77 | 1.04 | 0.78 | | SEM2 | 3.61 | 0.95 | 0.89 |
| VIS4 | 2.81 | 1.16 | 0.89 | | SEM3 | 3.73 | 1.04 | 0.84 |
| ACC1 | 3.65 | 1.12 | 0.87 | | PRA1 | 3.58 | 1.05 | 0.78 |
| ACC3 | 3.02 | 1.15 | 0.85 | | PRA3 | 3.80 | 1.00 | 0.74 |
| ACC4 | 3.59 | 1.04 | 0.88 | | PRA4 | 3.35 | 1.08 | 0.82 |
| CON1 | 3.59 | 1.25 | 0.80 | | | | | |
| CON2 | 3.50 | 1.24 | 0.82 | | | | | |
| CON3 | 3.22 | 1.23 | 0.67 | | | | | |

MAL: Malleability

PAR: Participation

UTD: Up-to-dateness

ANN: Annotation

VIS: Visualization

ACC: Accessibility

CON: Consistency

MOD: Modularity

SHS: Shared syntax

SYN: Syntactic capacity

SEM: Semantic capacity

PRA: Pragmatic capacity

*Table 27: Descriptive statistics, AVE, CR, CA*

| | MAL | PAR | UTD | ANN | VIS | ACC | CON | MOD | SHS | SYN | SEM | PRA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AVE | 0.63 | 0.82 | 0.73 | 0.81 | 0.7 | 0.75 | 0.59 | 0.74 | 0.7 | 0.54 | 0.66 | 0.61 |
| CR | 0.77 | 0.9 | 0.89 | 0.89 | 0.88 | 0.9 | 0.81 | 0.89 | 0.87 | 0.78 | 0.85 | 0.83 |
| CA | 0.44 | 0.78 | 0.82 | 0.77 | 0.79 | 0.84 | 0.67 | 0.82 | 0.79 | 0.6 | 0.74 | 0.68 |

*Table 28: Descriptive statistics, Squared Inter-construct correlations (AVE on main diagonal)*

| | MAL | PAR | UTD | ANN | VIS | ACC | CON | MOD | SHS | SYN | SEM | PRA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MAL | 0.63 | | | | | | | | | | | |
| PAR | 0.06 | 0.82 | | | | | | | | | | |
| UTD | 0.10 | 0.26 | 0.73 | | | | | | | | | |
| ANN | 0.24 | 0.18 | 0.10 | 0.81 | | | | | | | | |
| VIS | 0.22 | 0.12 | 0.19 | 0.08 | 0.70 | | | | | | | |
| ACC | 0.12 | 0.19 | 0.32 | 0.07 | 0.16 | 0.75 | | | | | | |
| CON | 0.23 | 0.06 | 0.09 | 0.07 | 0.14 | 0.22 | 0.59 | | | | | |
| MOD | 0.18 | 0.08 | 0.20 | 0.04 | 0.14 | 0.11 | 0.21 | 0.74 | | | | |
| SHS | 0.09 | 0.12 | 0.31 | 0.02 | 0.10 | 0.31 | 0.16 | 0.19 | 0.70 | | | |
| SYN | 0.07 | 0.13 | 0.10 | 0.10 | 0.08 | 0.16 | 0.34 | 0.24 | 0.25 | 0.54 | | |
| SEM | 0.19 | 0.03 | 0.06 | 0.21 | 0.18 | 0.11 | 0.15 | 0.06 | 0.05 | 0.14 | 0.66 | |
| PRA | 0.20 | 0.06 | 0.02 | 0.19 | 0.06 | 0.06 | 0.09 | 0.04 | 0.03 | 0.11 | 0.33 | 0.61 |

MAL: Malleability
PAR: Participation
UTD: Up-to-dateness
ANN: Annotation
VIS: Visualization
ACC: Accessibility
CON: Consistency
MOD: Modularity
SHS: Shared syntax
SYN: Syntactic capacity
SEM: Semantic capacity
PRA: Pragmatic capacity

# Paper E – Design principles for turning architectural models into boundary objects

*Table 29: Bibliographical metadata on Paper E*

| Attribute | Value |
|---|---|
| Title | Design principles for turning architectural models into boundary objects |
| Author(s) | Abraham, Ralf<br>University of St. Gallen, Müller-Friedberg-Strasse 8, 9000 St. Gallen, Switzerland<br>ralf.abraham@unisg.ch |
| Selected approach for order of authors | Sequence determines credit |
| Publication outlet | Architectural Coordination of Enterprise Transformation |
| Publication type | Book section |
| Publication year | forthcoming |
| Rating (Jourqual 2.1) | n/a |
| Publication status | Accepted for publication |

*Abstract*

n/a

*Keywords*

n/a

## E.1 Introduction

The diversity of the affected organizational entities (e.g., business units, divisions) in an enterprise transformation is mirrored in the diversity of the affected stakeholder groups: an enterprise transformation is typically is a collaborative endeavour of diverse stakeholder groups such as enterprise architects, project/program/portfolio managers, or managers of the affected business units. Stakeholder groups that experience regular interactions and share similar working methods can be regarded as communities of practice. "Community of practice" is a term coined by Wenger (2000) to describe a group of people that (1) share a joint area of concern (e.g., share the same tasks in an organization or are interested in the same topics); (2) regularly interact within a set of community-specific norms and relations, and (3) possess a shared repertoire of resources such as languages, methods, tools, stories, or other communal artefacts. A group of stakeholders who experience regular interaction and share similar working methods can be regarded as communities of practice.

Differences among the communities of practice involved in an enterprise transformation may be caused by multiple reasons: political interests, past experiences, or cultural differences as discussed in section 2. Differences in organisational subcultures can lead to both positive and negative consequences: while diversity can be a valuable asset on the one hand, leading to out-of-the-box thinking and innovation, diversity may on the other hand also lead to communication defects.

When communication defects among communities of practice occur, shared understanding on transformation goals and each other's plans and objectives may be lost, or may not even exist in the first place. The need for collaboration among diverse communities of practice is well-recognized in literature (Carlile 2004; Karsten et al. 2001; Nicolini et al. 2012), and shared understanding is regarded as a key success factor for successful ET (Bisel and Barge 2010; Elving 2005; Ford and Ford 1995; Stensaker et al. 2008). Oftentimes, enterprise transformations fail (Kotter 1996; Sarker and Lee 1999), with one particular reason for failure being a lack of shared understanding (Okhuysen and Bechky 2009). We adopt a definition of shared understanding as the "degree of cognitive overlap and commonality in beliefs, expectations, and perceptions about a given target" (Cohen and Gibson 2003, p. 8).

To convey information, and to improve shared understanding among communities of practice during enterprise transformation, one of the major communication devices are models. Multiple views on an enterprise can be covered with the appropriate models (e.g., business process models or software models). To match the diversity of communities of practice in enterprise transformation, enterprise architecture (EA) models appear promising: EA models address dependencies across partial views of an enterprise (e.g., business, technology), and are at a higher level of abstraction than models concerned with partial views. EA models are of interest to many diverse stakeholder groups because of the holistic overview they provide (Tamm et al. 2011; van der Raadt et al. 2010).

Differences in knowledge, goals, and values among communities of practice can be conceptualized as knowledge boundaries. In this section, we focus on knowledge translation, i.e. overcoming boundaries of interpretation. Carlile (2004) distinguishes three types of knowledge boundaries between communities of practice that become increasingly complex to cross: syntactic, semantic, and pragmatic knowledge boundaries. Only after a way has been found to establish shared understanding at these boundaries, knowledge can be transferred, translated, or transformed among the involved communities of practice.

A syntactic boundary exists due to different vocabulary between communities of practice. To create shared understanding at a syntactic knowledge boundary, a common lexicon must be developed (Carlile 2004; Kotlarsky et al. 2012).

A semantic boundary exists when communities of practice attribute different meanings to concepts, and have different interpretations of concepts (Carlile 2004; Hawkins and Rezazade M 2012). To create shared understanding at a semantic knowledge boundary, common meanings must be developed by translating and negotiating among the different meanings of the involved communities (i.e., by identifying and resolving differences).

Finally, a pragmatic knowledge boundary exists when communities of practice have different interests which affect their ability and willingness to share knowledge. To create shared understanding at a pragmatic knowledge boundary, common interests among the communities of practice must be developed. When developing common interests, communities accept the possibility of altering their cognitive frames and having their knowledge structures transformed (Carlile 2002). In other words, they move towards each other in negotiating a compromise.

Boundary objects are a potential means to cross the aforementioned knowledge boundaries if they possess a syntactic, semantic, or pragmatic capacity (Rosenkranz et al. 2014). In this subsection, we focus on semantic knowledge boundaries, and those boundary object properties that enable a semantic capacity. At a semantic knowledge boundary, both the architect and the EA model play an important role in establishing shared understanding. Therefore, we decide to first invest in building a capacity for this particular knowledge boundary. We do not address syntactic knowledge boundaries, as these are likely covered by existing EA models already (Rosenkranz et al. 2014; Valorinta 2011). Moreover, a syntactic capacity may be insufficient to create shared understanding in an ET scenario, where the diversity among communities of practice is exceptionally large, and the encountered knowledge boundaries may be more complex than a syntactic knowledge boundary. We also do not address pragmatic knowledge boundaries, where the focus strongly shifts away from objects to the role of architects (Abraham et al. 2013; Levina and Vaast 2005; Rosenkranz et al. 2014). Communities of practice need to find common interests to develop common solutions at such a knowledge boundary (e.g., agree on transformation goals or a concrete implementation strategy).

## E.2 Boundary objects

Boundary objects are abstract or physical artefacts that support knowledge sharing and coordination among different communities of practice by providing common ground. We follow the definition of Winter and Butler (2011): “By identifying ‘lowest common denominators,’ critical points of agreement, or shared surface referents, boundary objects provide a sufficient platform for cooperative action—but they do so without requiring the individuals involved to abandon the distinctive perspectives, positions, and practices of their ‘base’ social world.” This definition highlights two central aspects of boundary objects: interpretive flexibility and retaining a community’s identity.

(1) Interpretive flexibility: Boundary objects provide common ground among communities of practice. When they are used for a shared purpose of multiple communities of practice, boundary objects provide a common point of reference and are thus “weakly structured in common use” (Star and Griesemer 1989). However, each of the communities involved uses the boundary object on a more detailed level for its specific purposes, therefore making the object “strongly structured in individual site use” (Star and Griesemer 1989). Put differently, boundary objects are artefacts carrying de-contextualized information: Only within the communities involved does the information contained in a boundary object receive context (Hawkins and Rezazade M 2012; Landry et al. 2009).

(2) Retaining identity: While providing lowest common denominators, a shared point of reference, boundary objects do not aim to level the differences between the involved communities (i.e., to replace any other objects or practices the communities work with): Instead, they acknowledge each community’s individual identity and allow it to preserve the practices of its social world.

Examples of boundary objects include physical objects such as prototypes (Carlile 2004), intangible objects like shared IT applications (Pawlowski and Robey 2004), maps and models (Star and Griesemer 1989), and abstract conceptualizations such as standardized forms and repositories (Carlile 2004; Star and Griesemer 1989).

### E.2.1 Boundary object properties

In previous work, we have taken a boundary object perspective on EA models (Abraham 2013) and proposed a set of properties for overcoming various knowledge boundaries (Abraham et al. 2013). These properties are described as follows. For a detailed description, see (Abraham 2013):

- *Modularity* enables communities to attend to specific areas of a boundary object independently from each other, such as attending to individual portions of an ERP system.
- *Abstraction* serves the interests of all involved communities by providing a common reference point on a high level of abstraction. Local contingencies are eliminated from high-level views to highlight the commonalities.
- *Concreteness* addresses specific problems relevant to specific communities. Communities are able to specify their concerns and express their knowledge related to the problem at hand. Thus, interpretive flexibility is provided.
- *Shared syntax* provides a common schema of information elements, so that local use of information objects is uniform across communities.
- *Malleability* entails that boundary objects are jointly transformable to support the detection of dependencies and the negotiation of solutions.
- *Visualization* entails that boundary objects do not rely on verbal definitions, but possess a graphical or physical representation (e.g., a drawing or a prototype).
- *Annotation* enriches boundary objects with additional information by individual communities in order to provide context for local use.
- *Versioning* traces changes to boundary objects, along with their rationale. Additional context is provided by reconstructing the chronological evolution of the boundary object.
- *Accessibility* includes informing interested communities about the boundary object using appropriate communication channels and other measures aimed at helping communities to use the boundary object, such as trainings. As a result, the boundary object is easier to access for the involved communities.
- *Up-to-dateness* includes timely communication of changes to the involved communities as well as responsibilities and processes for updating the boundary object.
- *Stability* implies that the structure and underlying information objects of a boundary object remain stable over time. Despite different local uses and annotations, boundary objects provide a stable reference frame: While changes at the

periphery are possible, the core of the boundary object remains stable and recognizable.
- *Participation* means that relevant communities should be involved in the creation and maintenance of the boundary object, and that users should also include top management.

Based on a series of expert interviews (Abraham et al. 2013), we consider the following properties to enable syntactic, semantic, and pragmatic capacities in boundary objects:

- *Syntactic knowledge boundaries*: Accessibility and Shared syntax
- *Semantic capacity*: Visualization, Modularity, Abstraction/Concreteness, and Stability
- *Pragmatic capacity*: Participation and Up-to-dateness
- Not supported by our interview data: Malleability, Annotation, and Versioning

We will therefore focus one the boundary object properties of visualization, modularity, abstraction/concreteness, and stability. These properties are essential for a semantic capacity.

### E.2.2 EA models as boundary objects

Nicolini et al. (2012) argue for considering a broad range of object types when analysing communication among communities of practice. They present a framework of different object types that support collaboration among communities of practice: material infrastructures, boundary objects, epistemic objects, and activity objects.

Material infrastructures remain in the background and only become visible when they cease functioning. Examples of material infrastructure are communication systems (e.g., email, phone), or project documents. Activity and epistemic objects are central objects to the organization's mission, e.g. the products to be developed, or representations thereof. They motivate collaborative efforts (epistemic object) or stimulate negotiations (activity objects). The similarities between activity and epistemic objects become evident from the fact that the same instance is provided as an example for both object types in previous works (namely, a bioreactor (Nicolini et al. 2012) and an intellectual property database (Neyer and Maicher 2013)).

Boundary objects are positioned between material infrastructures and epistemic objects/activity objects. They provide interfaces between communities of practice, but they are the means to enable collaboration in the first place, rather than the ends of collaborative efforts. They are much more stable and defined than activity objects or epistemic objects, yet still malleable and interpretively flexible enough to not (yet) be considered material infrastructures. Different communities of practice can thus detect complementarities, differences and dependencies between their own perspectives and the perspectives of others, and can incorporate others' perspectives into their own.

Out of the previously discussed objects in collaboration, we opt for conceptualizing EA as boundary objects. EA models are not ends in themselves, but they are rather used by organizations to derive future benefits, for example supplying information to decision makers, increasing business-IT alignment or improving communication. EA models are not the ultimate output of an organization, or the very reason for an organization's existence—those would be the products or services the organization eventually produces.

In enterprise transformation, the primary purpose of boundary objects is to provide a means for translation among different perspectives, not to motivate collaborative efforts in the first place. In ACET, therefore, EA models are conceptualized as boundary objects, as they are a means of architecture for achieving the ends (coordination, and establishing shared understanding as an important facet of coordination) in a specific context (enterprise transformation).

## E.3 Semantic boundary object capacities

Having motivated our choice of the boundary object lens to improve shared understanding in enterprise transformation, we now take a more detailed look into those properties that enable a semantic boundary object capacity: visualization, modularity, abstraction/concreteness, and stability.

### E.3.1 Visualization

By improving the cognitive effectiveness, a boundary object can be made more accessible to different communities and easier to understand (Boland and Tenkasi 1995; Henderson 1991). To this end, a number of visualization principles are provided (Moody 2009). Yet, these principles are general-purpose principles, applicable to any (conceptual) model. To assess the feasibility of the visualization principles for our specific purpose—turning an EA model into a boundary object—we performed an experiment.

#### E.3.1.1 Experimental setup

We performed an experiment with the participants of an EA seminar held in Finland in October 2013. This seminar was attended by 11 participants pursuing a PhD in information systems with a specific research interest in the EA field. Some of the participants had prior industry experience. These participants serve as proxies for future enterprise architects. We presented them a fictitious, illustrative enterprise transformation scenario that described a merger between two telecommunication service providers. The communities of practice involved were the transformation management team on the one hand, and the managers of the IT unit of one of the providers on the other hand. In the scenario, a capability map was envisioned to be helpful in identifying gaps or overlaps in the capability structure between the two individual service providers and the future merged enterprise. A capability map is an artefact type that aggregates software components into capabilities. Capabilities decouple business process activities from software components: business process activities do not access software components directly, but indirectly via capabilities (Winter 2010). Figure 10 shows the initial capability map.

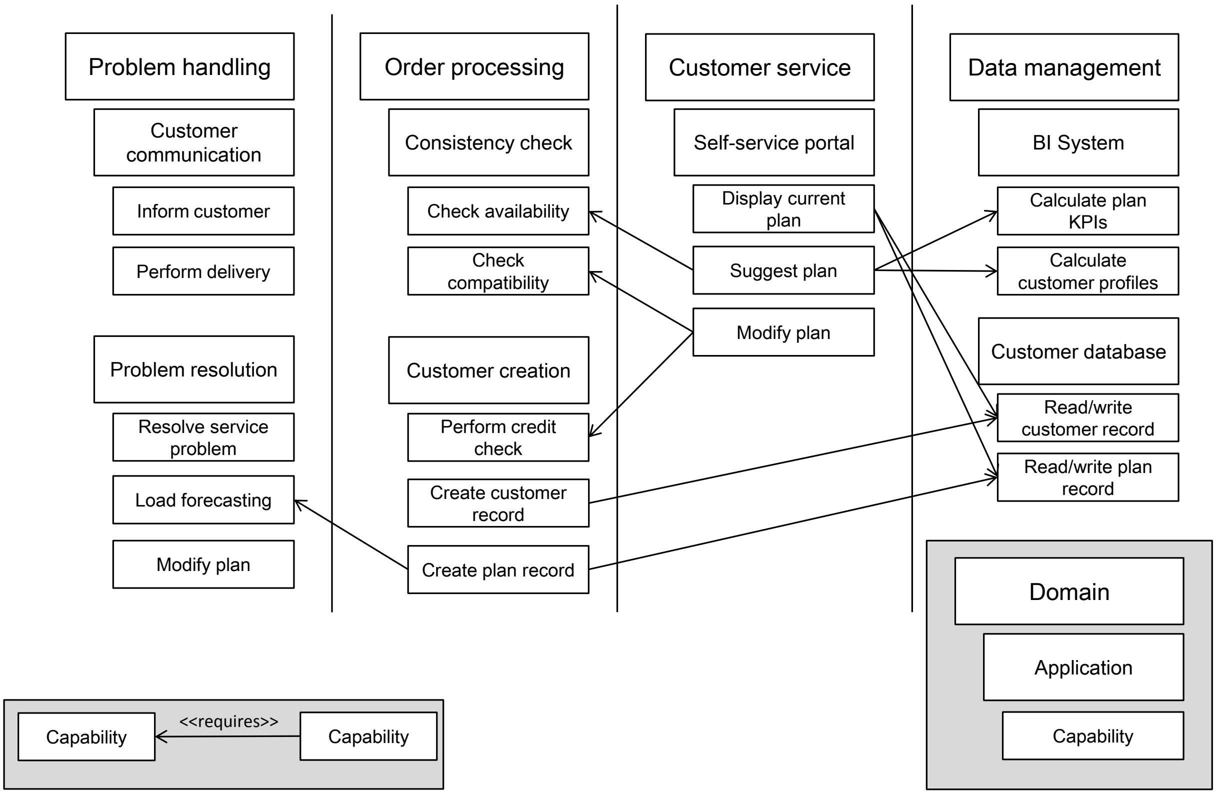


*Figure 10: Initial capability map*

We specifically selected visualization principles which improve the cognitive effectiveness for novices rather than for experts (Moody 2009, p. 772). The rationale behind this decision is that the principles shall be applied to create boundary objects for a heterogeneous set of communities of practice, rather than detailed models for a single expert community. The following visualization principles have been selected from Moody (2009, p. 772): perceptual discriminability, semantic transparency, dual coding, and complexity management. The visualization principle graphic economy—calling for a cognitively manageable number of graphic symbols—has not been selected, as only a very specific model has been investigated that did not contain an excessive number of different visual constructs.

After the visualization principles had been explained, the participants applied them to the initial capability map. The stated objective of this exercise was to turn the capability map into a boundary object. The participants were given 20 minutes to perform this task (paper-based rather than electronically). After the experiment, the participants assessed for each visualization principle (1) whether they considered it useful for constructing a boundary object, and (2) whether they found it easy to use. Both questions were rated on 5-point Likert scales, ranging from not at all useful/easy to use to very useful/easy to use. The visualization principles are explained below. For each, the original model is depicted on the left hand side, and the altered model (after application of the principle) is depicted on the right hand side.

*Perceptual discriminability*

The degree of perceptual discriminability indicates how easily and accurately different graphical symbols can be discriminated from one another. Variations in shape ("primacy of shape") or the use of colour as a second, redundant coding factor are examples of visualization principles that can improve perceptual discriminability. Figure 11 gives an example.

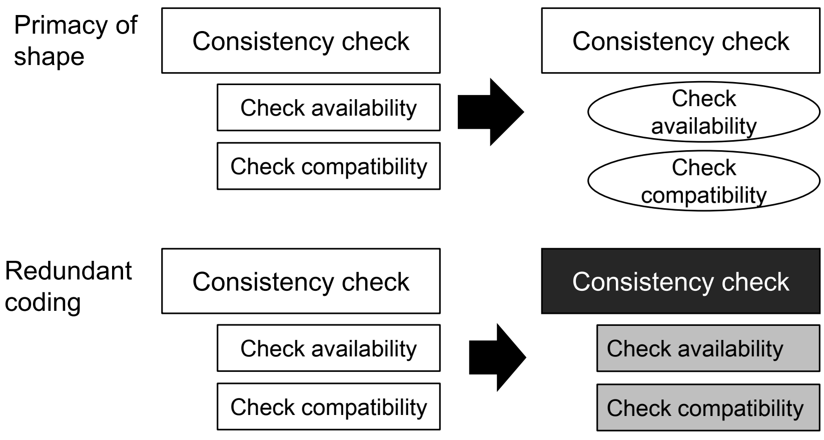


*Figure 11: Perceptual discriminability*

*Semantic transparency*

The degree of semantic transparency indicates how easily the meaning of a graphical symbol can be guessed from its appearance. Figure 12 gives an example where the fact that two capabilities belong to the same application is highlighted visually on the right-hand side.

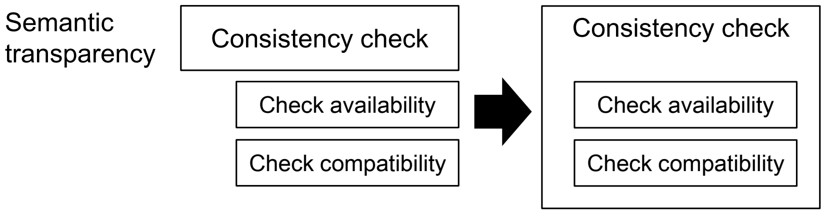


*Figure 12: Semantic transparency*

*Dual coding*

Dual coding refers to the representation of relationships both textually and graphically. Figure 13 presents an example.

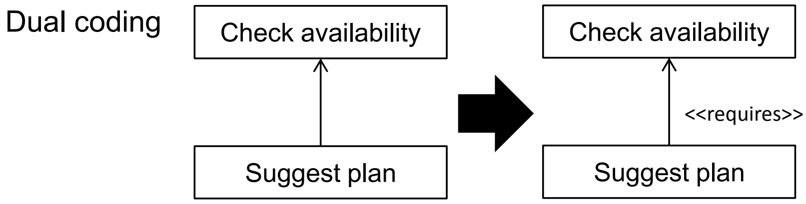


*Figure 13: Dual coding*

*Complexity management*

Complexity management refers to the use of techniques such as abstraction mechanisms to reduce the complexity of a representation. Figure 14 shows an example of a capability map broken down into several layers. Individual layers (L0, L1, L2) can be hidden from the users in order to reduce the overall complexity of the diagram.

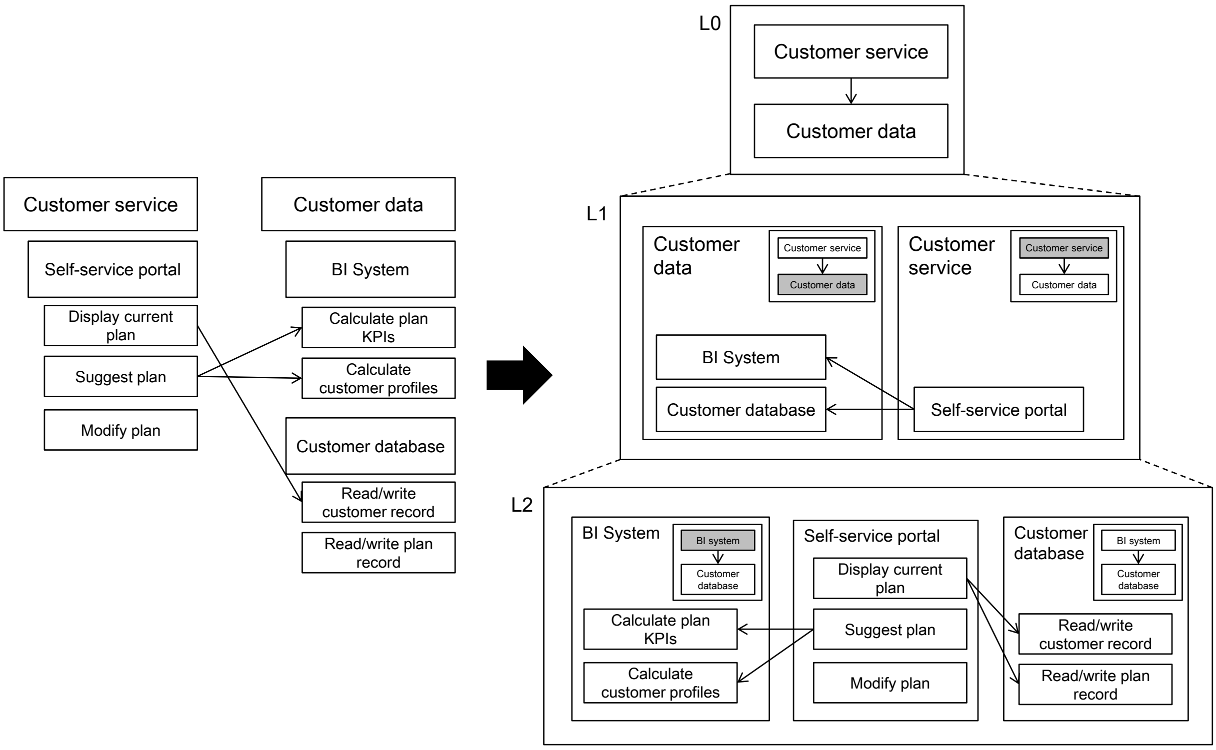


*Figure 14: Complexity management*

*Performance attributes*

This is a design rather than a visualization principle, as it does not relate to the representation of the capability map, but to its information content. Capabilities can be supplemented with performance attributes, indicating requirements towards the quality of service level (e.g., in terms of time, availability, or execution speed). Figure 15 gives an example.

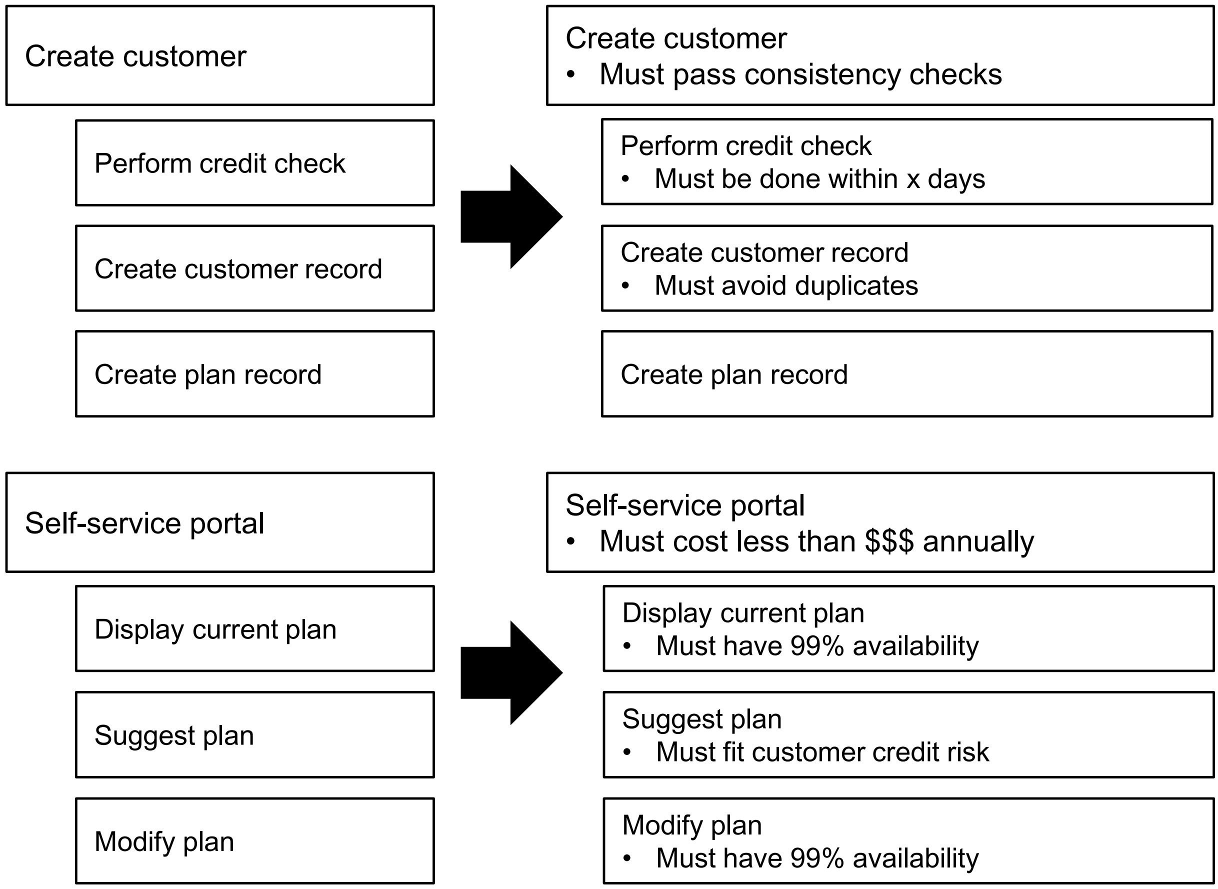


*Figure 15: Performance attributes*

#### E.3.1.2 Experimental results

Figure 16 shows how the participants assessed perceived usefulness and perceived ease of use for each of the presented visualization principles.

Complexity management appears to be the most useful visualization principle, but also the most difficult to use. Semantic transparency, on the other hand, is considered both very useful and easy to use. Providing additional information on service quality also shows a favourable balance of usefulness and ease of use. On the other hand, visualization principles such as perceptual discriminability (exemplified via primacy of shape and redundant coding) and dual coding are considered comparatively less useful for the purpose of creating a boundary object.

Overall, combining the visualization principles of semantic transparency, complexity management, and the performance attributes principle (i.e., those principles with a perceived usefulness higher than 4.00) can be seen as the most promising candidates for creating cognitively efficient boundary objects.

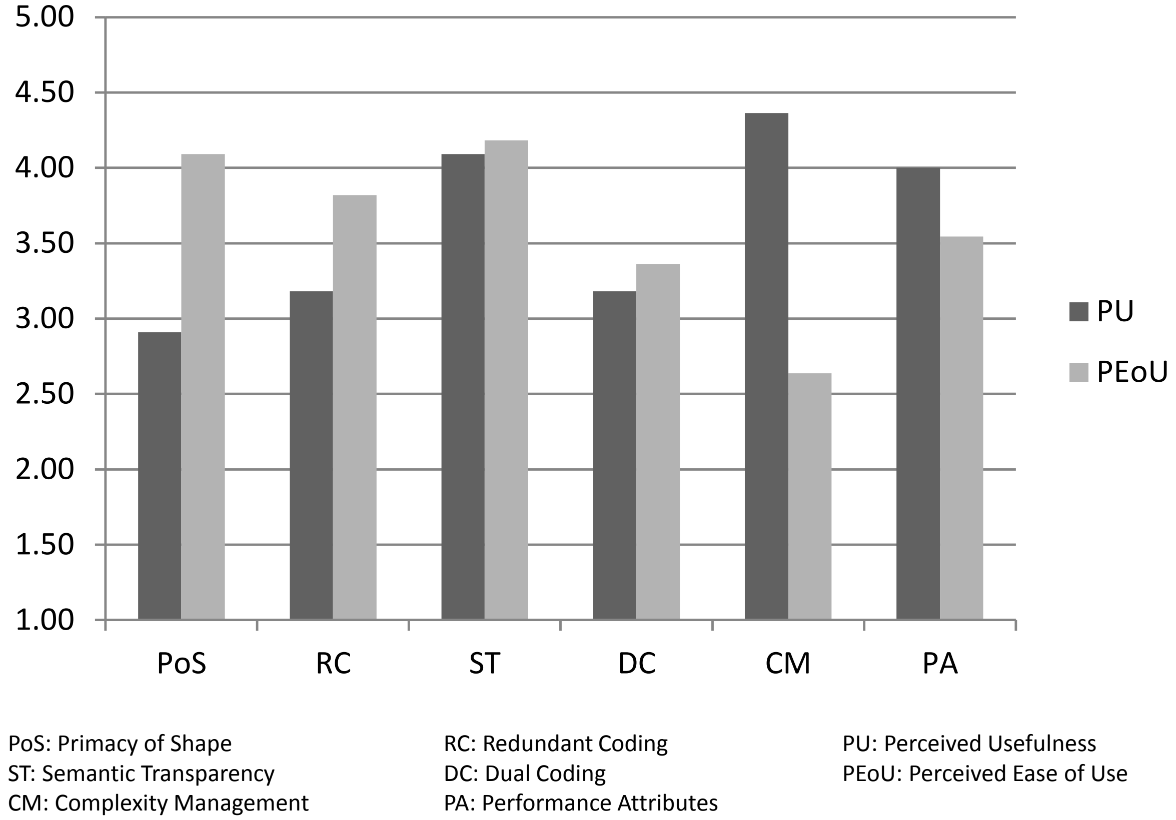


*Figure 16: Perceived usefulness and perceived ease of use per principle*

Yet, the experimental results must be assessed with caution: a model does not become a boundary object at design time, but only during actual application. We asked designers of EA models—in the specific case a capability map—whether applying a certain technique would increase the potential of the capability map to be adopted as a boundary object. Our respondents could therefore only assess a "designated boundary object", which does not automatically become a "boundary object-in-use" (Levina and Vaast 2005). Moreover, as enterprise architects, all our respondents belonged to the same community of practice.

### E.3.2 Modularity

When several communities of practice share a boundary object, a major design decision is when and by whom the information is filtered. Two extremes are possible: On the one hand, all communities of practice could look at the same model, which contains entirely unfiltered information. In this case, the users will have to contextualize and filter the available information themselves (user-based contextualization). On the other hand, a viewpoint could be provided for each community of practice group, filtering the information that is considered relevant from the object designer's point of view. In this case, information filtering is already done at design time, when the viewpoints are constructed (designer-based contextualization). An example for user-based contextualization would be a global model at a high level of abstraction. Here, all communities of practice look at different parts of the overall model, but would be able to see other communities of practice' areas of concern at the periphery of their own core area. Abraham (2013) provides an example of a financial figures sheet at an insurance company, where the same sheet is used by both the business community to define objects such as contracts and premiums, and by the data warehouse community to identify which database tables to query for creating reports. An example for designer-based contextualization would be a model with pre-defined viewpoints for individual communities of practice, so that one group of communities of practice does not see the information that is intended for other communities of practice.

In another example in the air traffic management domain, the findings of Landry et al. (2009) also indicate that user-based contextualization enabled superior air traffic controller performance than designed-based contextualization. Air traffic controllers explicitly preferred getting the whole picture and then doing the filtering themselves to receiving information from a pre-defined viewpoint. From these findings, Landry et al. (2009) propose the following design guidelines:

(1) Provide a common picture for all collaborators
(2) Minimize the amount of information pre-processing by the designers. Leave information filtering to the user
(3) Provide continuous updates on changes to all collaborators (i.e., to all involved communities of practice)

Concerning the modularity property, we argue that user-based contextualization is more appropriate for designing a boundary object than designer-based contextualization. First, not all relevant communities of practice that may eventually use the boundary object are known a priori. Hence, one cannot pre-define views that suit any potential user. Second, by showing what is happening at the periphery, communities of practice can more easily transfer knowledge between each other.

### E.3.3 Abstraction/concreteness

Models on different abstraction levels should be linked. Models on a high level of problem description aid in translating among different perspectives and generate common meanings. Models on a more detailed level are beneficial for establishing a common terminology by exposing community-specific vocabulary. The interlinking among different levels of problem description is also part of the complexity management visualization principle.

In a study set in the domain of database modelling, Parsons (2003) reports on the differences between students' understanding of classification structures, depending on whether multiple local schemas or one global schema is provided. The findings partly confirm those of Landry et al. (2009), namely that a global schema improves communication by relieving the subjects from manual integration effort (i.e., having to collect information from a variety of viewpoints). However, this is only the case when the information presented in the global schema is complementary to the information in local schemas (e.g., the fact that two synonyms "client" and account" refer to the same entity can be more efficiently shown on a global schema). When there are conflicts between the global schema and the local schemas, the participants showed better problem understanding (hence better organizational communication) when presented with a number of local (i.e., community-specific) schemas than with a single global schema. Being able to rely on local representations helped subjects to identify and understand differences among their viewpoints. The authors conclude that a global schema should be constructed to leverage its effect on improving organizational communication when the viewpoints/classification/interests of two communities of practice are complimentary. However, local schemas should be preserved in order to be able to detect differences in interpretation (semantic boundary) and help the affected communities of practice resolve their conflicts (thereby crossing a pragmatic boundary).

Concerning the required balance between the properties of abstraction and concreteness, we argue for combining de-contextualized with contextualized models. When differences arise not only in interpretations but also in interests, organizational communication is improved by providing local schemas that can be consulted to resolve these conflicts: a high level of abstraction on the overall model is combined with low levels of abstraction on the linked detail models. This enables communities of practice to switch back and forth between global and local models (Pareto et al. 2010), combining the effectiveness of information retrieval in the global model with the conflict detection and resolution-capability of the local model. In the case of EA models for transformation, a global to-be model of the future state should be complemented by local models that depict to-be states of individual domains, like process architectures of organizational divisions. In case of disagreement, communities can then drill down from the global model to more specific views to detect and/or resolve differences.

### E.3.4 Stability

Boundary objects need to have certain stability, a robust frame, to be considered trustworthy and legitimate sources of information. A boundary object that changes rapidly and, above all, unpredictably, tends to be ignored (Abraham 2013, p. 8) Another aspect the panellists stressed is stability: a constantly changing object fails to gain legitimacy and tends to be ignored. Yet, a boundary object must be kept up-to-date at the same time; otherwise, communities of practice might lose trust a boundary object that provides outdated information (Abraham et al. 2013, p. 35 f.). Release management processes (van der Hoek and Wolf 2003) can help to control the frequency of changes while regularly updating the contents, and thus balance between stability and up-to-dateness requirements. Change request towards a boundary object would then be collected, discussed, and evaluated (e.g., in an architectural board). Periodically, new versions would be released, ensuring that there is always an official version available.

## E.4 Development of boundary object design principles

Albeit design principles have been mentioned as "knowledge contribution" types (Gregor and Hevner 2013, p. 348), and "[p]rinciples of form and function" as part of an IS design theory (Gregor 2006, p. 329), a precise definition of the term "design principles" has not yet emerged. We shall adopt the definition of van Aken of a design principle as "a chunk of general knowledge, linking an intervention or artifact with a desired outcome or performance in a certain field of application" (2004, p. 228). To describe our design principles, we will use the core meta-model of Aier et al. (2011c) for EA design principles. Albeit our design object is different – boundary objects rather than EA – we consider the meta-model of Aier et al. (2011c) as applicable for describing boundary object design principles as well. Similar to EA design principles, we apply our design principles to achieve a desired outcome, we define an intended field of application, and we intend to create general knowledge, i.e. design principles on a generic level that may be refined for application in a specific enterprise. While our design object is specific (an EA model as a boundary object) rather than generic ("grand design", an entire EA), our design principles also serve the core architectural purpose of restricting design freedom, or guiding design choices (Dietz and Hoogervorst 2008). The core meta-model of an EA design principle consists of the following components (see Figure 17).

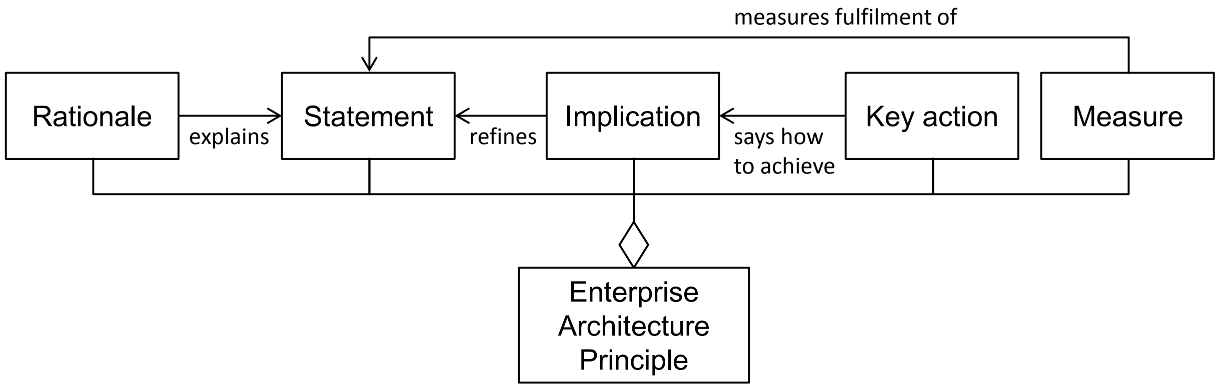


*Figure 17: Core meta-model of an EA principle (Aier et al. 2011c, p. 641)*

- The *rationale* provides the justification for applying the principle: why does applying this principle provide a benefit?
- The *statement* describes the objective of the principle: what should be done?
- The *implications* describe how the objective of the principle can be achieved: how can it be implemented?
- The *key actions* describe specific actions for implementing the principle.
- *Measures* say how the implementation success of the principle can be measured.

Except for key actions, all elements of this core meta-model are on a generalized level: they apply to multiple enterprises. Key actions, on the other hand, must be taken in a specific enterprise: what does this mean for us, considering our unique context? For example, Aier (2014) argues that the organizational culture of an enterprise impacts the way principles should be applied. Since we intend to build generally-applicable principles for designing boundary objects in enterprise transformation, we do not elaborate on key actions. Rather, these have to be derived with a specific enterprise and its context in mind.

### E.4.1 Visualization

Table 30 shows the design principle for the visualization property.

*Table 30: Visualization design principle*

| Component | Explanation |
|---|---|
| Rationale | Cognitive efficiency is essential for understanding and accepting models. |
| Statement | Design cognitively efficient EA models to improve shared understanding in ET. |
| Implication | Apply the following design and visualization principles that provide a desirable balance between perceived usefulness and perceived ease of use<br>• semantic transparency<br>• complexity management<br>• performance attributes (design principle) |
| Key action | <To be defined per enterprise> |
| Measure | • Less time is spent for finding information in the model (i.e., model content can be grasped faster)<br>• Less misunderstandings occur while reading the model |

### E.4.2 Modularity

Table 31 shows the design principle for the modularity property.

*Table 31: Modularity design principle*

| Component | Explanation |
|---|---|
| Rationale | User-based contextualization is more suitable for creating shared understanding than designer-based contextualization. |
| Statement | Provide all information in one view, so that users do the filtering themselves. |
| Implication | Provide one common view of the model to all user groups.<br>• Group information relevant to one user group (e.g., in columns, or spatially in a diagram)<br>• Highlight parts of the overall model graphically, to help communities of practice locate their areas of concern<br>• Provide users with the ability to discover information adjacent to their own area of concern |
| Key action | <To be defined per enterprise> |
| Measure | • Existence of only one common view to capture the information previously stored in multiple views |

### E.4.3 Abstraction/concreteness

Table 32 shows the design principle for the abstraction/concreteness property.

*Table 32: Abstraction/concreteness design principle*

| Component | Explanation |
|---|---|
| Rationale | Depending on the level of cooperation, resp. the degree of conflict, one global or several local models are preferable. |
| Statement | Provide users with the ability to navigate between different levels of problem description. |
| Implication | Combine global, de-contextualized models with local, community-specific models.<br>• A global model is preferred when communities of practice have common meanings and common interests. Multiple local models are preferred when communities of practice need to develop common meanings or common interests<br>• Explicate the links between models on different levels of abstraction |
| Key action | <To be defined per enterprise> |
| Measure | • Users may conveniently navigate between different levels of abstraction |

### E.4.4 Stability

Table 33 shows the design principle for the stability property.

*Table 33: Stability design principle*

| Component | Explanation |
|---|---|
| Rationale | A stable boundary object is able to gain legitimacy from communities of practice, while a boundary object that is perceived as too volatile tends to be ignored. |
| Statement | Provide a boundary object whose structure remains stable and recognizable across communities of practice. |
| Implication | Balance between the goals of stability on the one hand, and providing timely updates on changes on the other hand.<br>• To minimize the frequency of changes and prevent ad-hoc manipulation, define a change management process<br>• Collect change requests, assess required changes, and release new versions periodically |

| Component | Explanation |
|---|---|
| | • Define a release management process, so that there is always one official version of the boundary object in circulation |
| Key action | <To be defined per enterprise> |
| Measure | • Change and release management processes defined according to officially sanctioned standards<br>• Only one official version of the boundary object in circulation |

## E.5 Conclusion

We have analysed the properties of visualization, modularity, abstraction/concreteness, and stability that are central for semantic capacity to designing boundary objects. From an experiment with PhD candidates in the field of EA, we have identified two visualization principles—semantic transparency and complexity management—that are, combined with the additional principle of performance attributes, especially relevant for boundary object construction in ET.

For the modularity, abstraction/concreteness and stability properties, we have derived design principles from existing literature. We conclude that a boundary object should be contextualized by the users instead of by the designers, that different levels of abstraction should be interlinked to detect conflicting local interpretations, and that stability and up-to-dateness requirements should be balanced via a release management process.

Like with any research, the findings presented here must be interpreted cautiously. The sample in the experiment contained merely eleven participants who were potential creators, but only a subset of the end users of the proposed boundary object. The principles for modularity, abstraction/concreteness and stability have been derived from experimental studies in literature that did not cover the specific phenomenon of enterprise transformation. Nevertheless, the four design principles provide actionable advice to enterprise architects, so that they can understand and subsequently enhance the capability of their tools (i.e., architectural models).

# Paper F – Fail Early, Fail Often: Towards Coherent Feedback Loops in Design Science Research Evaluation

*Table 34: Bibliographical metadata on Paper F*

| Attribute | Value |
|---|---|
| Title | Fail Early, Fail Often: Towards Coherent Feedback Loops in Design Science Research Evaluation |
| Author(s) | Abraham, Ralf; Aier, Stephan; Winter, Robert<br>University of St. Gallen, Müller-Friedberg-Strasse 8, 9000 St. Gallen, Switzerland<br>ralf.abraham@unisg.ch, stephan.aier@unisg.ch, robert.winter@unisg.ch |
| Selected approach for order of authors | Sequence determines credit |
| Publication outlet | Proceedings of the International Conference on Information Systems (ICIS 2014) |
| Publication type | Conference paper (Research-in-progress) |
| Publication year | forthcoming |
| Rating (Jourqual 2.1) | A |
| Publication status | Accepted for publication |

*Abstract*

We propose feedback loops that increase the coherence between evaluation activities in a design science research (DSR) process. While several scholars have proposed DSR cycles with frequent evaluation activities to provide timely feedback on design activities, the question of how to ensure coherence between these activities has remained largely unaddressed. Yet, coherence is essential to claim validity not only for the DSR artifact, but also for the DSR process.

Based on a review of existing DSR literature, we propose an approach that ensures coherence between initial problem definition and final evaluation activities by explicating the notion of relevance underlying the DSR project, and between design and construction activities by creating situational design specifications.

We exemplarily apply our approach to an ongoing DSR project. We conclude with a research agenda, where we build on the recent debate on generalizability in information systems to identify six fruitful avenues for further research.

*Keywords*

Design Science, Design method, Evaluation, Evaluation methods and criteria

## F.1 Introduction

As a science dealing with the artificial, information systems (IS) design science research (DSR) is different from natural, social, or human sciences. While the latter primarily produce descriptive knowledge, covering natural or social phenomena, DSR produces prescriptive knowledge: knowledge on means to achieve desired ends (Gregor 2009; Gregor and Hevner 2013; Hevner et al. 2004). While natural, social, and human sciences are primarily concerned with describing reality, eventually, their results may also bear traits of prescriptive knowledge (e.g., substances that lead to new drugs). By constructing artifacts, design science researchers create reality. In other words, "the phenomenon under study emerges as the research proceeds" (Sonnenberg and vom Brocke 2012b, p. 384). Hence, the DSR results need to be evaluated differently than contributions in natural or human sciences. In this paper, we follow the notion of evaluation by Gregor and Hevner (2013): showing that something is useful, based on criteria such as validity, utility, quality, or efficacy (Gregor and Hevner 2013, p. 350). We shall use evaluation as a generic term to refer to both the design product (evaluating the artifact) and the underlying DSR process (evaluating the process).

Theories in natural or human sciences are typically validated ex post, i.e., after they have been formulated. Validation yields either corroborating evidence in favor of the theory (e.g., by showing that the theory is accurate, simple, internally and externally consistent in explaining and/or predicting natural phenomena or human behavior), or it limits the scope of the theory (Kuhn 1977, p. 321). An ex post evaluation of an artifact, i.e., showing that an artifact is actually useful in the "three realities" of real tasks, real systems, and real users (Sun and Kantor 2006), is certainly desirable in DSR as well. However, focusing solely on ex post evaluations has serious drawbacks (Sonnenberg and vom Brocke 2012b).

(1) *Resource efficiency*: Both constructing an artifact, and testing it in the real world (if possible at all), consume enormous resources. There is considerable risk of wasting resources by missing design flaws until the artifact has been deployed. Such flaws

could include addressing the wrong problems (not doing the right things) or functional defects that compromise the artifact's performance (not doing things right).

(2) *Re-usability*: When only the design product is evaluated, rather than the design process itself, such a process cannot be re-used with confidence. A successful artifact could also be created ad-hoc, either by following intuition or by following a process that has never been evaluated. However, such an artifact could not be deemed constructed in a rigorous way. Only when the design process itself is evaluated, it can be expected to generate high-quality, predictable results.

(3) *Epistemology*: If only the design product can be evaluated, but not the design process itself, this would question the essential value of DSR. While DSR may also produce descriptive knowledge, (e.g., during problem identification activities), the ultimate goal of DSR is to produce prescriptive knowledge in the form of artifacts that eventually need to be evaluated (Österle et al. 2011). However, to claim scientific rigor for DSR results, the design process should be justified as well: following this process will, under specified circumstances, yield certain results (Karagiannis 2010). Design theories (Gregor and Jones 2007) aim at documenting knowledge obtained in design science in a rigorous way so that design decisions can be justified and design knowledge be communicated in the academic community.

Therefore, evaluation activities in DSR need to be conducted both while the artifact is being constructed (ex ante evaluation), and after the artifact has been constructed (ex post evaluation). Ex ante evaluations assess the design process, while ex post evaluations assess the design product. Combining ex ante and ex post evaluation leads to agile DSR processes: processes that can detect design flaws early, often, and therefore cost-efficiently (a paradigm dubbed "fail early, fail often" (Thomke and Reinertsen 2012)). The need for integration instead of separation between design and evaluation activities is also discussed in related fields like action design research (Sein et al. 2011). Still, many proposed DSR processes strongly focus on ex post evaluations (Hevner et al. 2004; Peffers et al. 2007). Only the more recent contributions by Sonnenberg and vom Brocke (2012b) and Venable et al. (2012) address both ex ante and ex post evaluations. In this research-in-progress paper, we extend the focus on ex ante evaluations. This extension implies that not just a single component of the overall DSR project is evaluated (the design product), but multiple components (the actual artifacts as well as the sequence of design activities that generate the artifact and form the underlying design process). However, these evaluation activities require different techniques, and are performed from different perspectives. While several works have addressed the needs for multiple, fast evaluation iterations (Nunamaker Jr et al. 1991; Sonnenberg and vom Brocke 2012b; Venable et al. 2012; Winter and Albani 2013) and some works have addressed the need for multiple evaluation perspectives (Frank 2007; Sonnenberg and vom Brocke 2012b; Venable et al. 2012), the question how to ensure coherence between different evaluation perspectives remains largely unaddressed.

The evaluation of a DSR process is only as strong as the weakest link in the chain. A desirable validation chain should therefore not only be agile, but also ensure coherence between the different evaluation perspectives, so that the entire DSR process can be evaluated. Thus, the drawbacks of ex post-only evaluations mentioned above can be addressed. We therefore ask the research question, *how can coherence between the evaluation perspectives in an agile DSR process be ensured*? To this end, we suggest coherent notions of relevance and situational design. We also identify fruitful areas for further research (research agenda). This paper is organized as follows. In section two, we discuss related work. We formulate an initial approach for ensuring coherence among evaluation activities in section three, and we provide an example of a coherent sequence of evaluation activities in section four. We conclude our paper with a discussion of current limitations and an outlook on our future research.

## F.2 Related work

The duality of design process and design product is highlighted by Nunamaker et al. (1991). They propose a systems development process as an information systems (IS) research method. Systems development is attributed a pivotal role: the result of the process (e.g., a database system as a design product) is seen as a “proof-of-concept” for the underlying “fundamental research”. Overall, systems development can be “thought of as a ‘proof-by-demonstration’" (Nunamaker Jr et al. 1991, p. 91), a research approach to choose when researchers aim at providing evidence for “the validity of the solution, based on the suggested new methods, techniques, or design” (Nunamaker Jr et al. 1991, p. 98).

Frank (2007) argues for multi-perspective evaluations. He proposes four perspectives for the evaluation of an artifact: an economic perspective, a deployment perspective, an engineering perspective, and an epistemological perspective. The economic perspective assesses whether using the artifact has a desirable cost-/benefit ratio. Challenges in this perspective include quantifying benefits (e.g., how to measure to what degree an artifact improves communication among stakeholders in an organization). The deployment perspective assesses how the users react towards an artifact. Relevant criteria in this perspective include understandability, users' attitudes towards the artifact, and adoption of the artifact. The engineering perspective assesses whether a solution implements the specified requirements. The epistemological perspective, finally, assesses whether an artifact fulfills the criteria of scientific rigor. The assumptions underlying the model design should not contradict existing theories; rather, existing (design) theories should be leveraged to inform the artifact design. This perspective also requires that the artifact and the design decisions are documented in a structured way.

In a frequently referenced DSR process model, Peffers et al. (2007) outline the activities of *problem identification and motivation*, *define the objectives for a solution*, *design and development*, *demonstration*, and *evaluation*. This process is then demonstrated in a number of case studies. The emphasis on ex post evaluations becomes clear from the naming of the activities in the DSR process model: the dedicated *evaluation* activity ("[o]bserve and measure how well the artifact supports a solution to the problem" (Peffers et al. 2007, p. 56)) is carried out after the *design and development* and the prototypical instantiation in the *demonstration* activity ("Demonstrate the use of the artifact to solve one or more instances of the problem" (Peffers et al. 2007, p. 55)).

In neighboring disciplines like software development, agile development processes (Dingsøyr et al. 2010; Dyba and Dingsøyr 2008) advocate to frequently revisit earlier development activities and to perform small, incremental rather than large, big-bang changes. Thus, rapid feedback on development activities can be provided, instead of delayed feedback that is received only after a major milestone has been reached (as would be the case with sequential development processes). Similarly, in business process management (Karagiannis 1995; Weske 2007), process life cycles are also concerned with constantly monitoring and iteratively improving the underlying artifact.

## F.3 Ensuring coherence between evaluation activities

Sonnenberg and vom Brocke (2012b) argue for reconsidering the traditional sequence of build first, evaluate later (denominated "build-evaluate pattern"). Instead, they propose a cyclic DSR process that alternates between four core activities ("Problem Identification-Design-Construct-Use"), and four evaluation activities. Hence, feedback loops from each evaluation activity (Eval 1 to Eval 4) allow for revisiting the preceding design activity. Together, these feedback loops form a feedback cycle, which runs counterclockwise to the clockwise DSR cycle (Sonnenberg and vom Brocke 2012a). While the feedback cycle will typically only revisit the preceding design activity in the event of a negative evaluation result, the design cycle is intended to be completed, alternating design and evaluation activities. The various design and evaluation activities, along with the produced outputs, a selection of applicable research methods, and the proposed linkages between evaluation activities to ensure coherence are illustrated in Figure 18. Note that we based our selection of applicable research methods on the peculiarities of the IS domain; for this reason, we do not discuss methods like formal proofs or simulations that are common in computer science, but may not be adequate for DSR projects which focus not only on technology, but also on social issues like use and adoption.

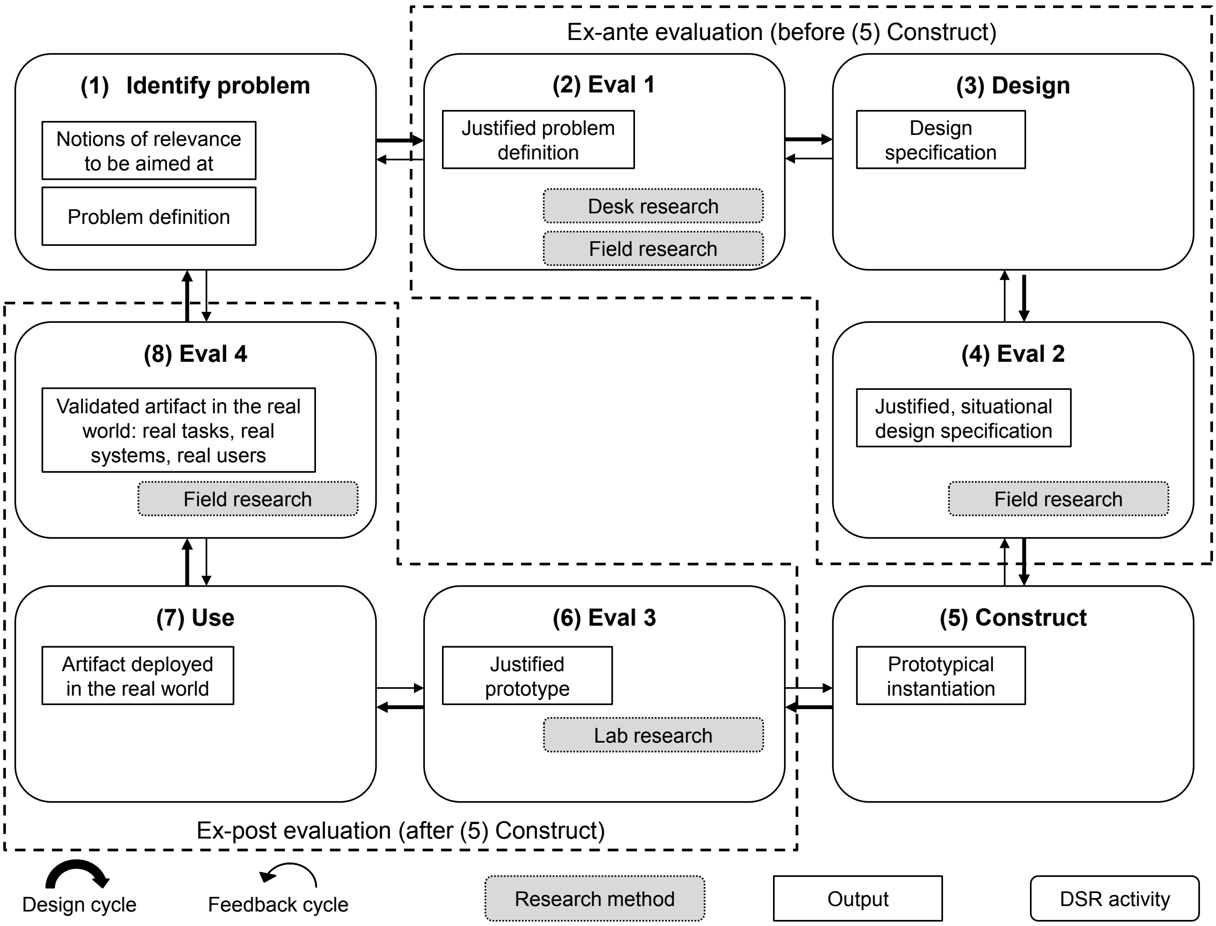


*Figure 18: Coherent design/feedback cycle based on Sonnenberg and vom Brocke (2012b)*

In the left part of Table 35, the evaluation activities (Eval 1–4) are matched to the preceding DSR process steps. For comparison, the corresponding evaluation perspectives from Peffers et al. (2007), Nunamaker et al (1991), and Frank (2007) are mapped against the Sonnenberg and vom Brocke (2012b) perspective in the right part of Table 35, where applicable. While the ex post evaluation activities Eval 3 and Eval 4 (i.e., prototypical instantiations and actual use in the "three realities") are covered by all DSR process, there is a shortage on perspectives on the ex ante evaluation activities Eval 1 and especially Eval 2.

*Table 35: Comparison of evaluation perspectives*

| Sonnenberg and vom Brocke (2012b) perspective | | | Comparison perspectives: (Frank 2007; Nunamaker Jr et al. 1991; Peffers et al. 2007) | | |
|---|---|---|---|---|---|
| Evaluation activity | Ex-ante/ Ex-post | Evaluated DSR activity | Corresponding DSR evaluation activity based on (Peffers et al. 2007) | Systems development research process (Nunamaker Jr et al. 1991) | Evaluation perspective (Frank 2007) |
| Eval 1 | Ex-ante | Problem Identification | No dedicated evaluation activity mentioned; Evaluation of the results from *problem identification and motivation* and *define the objectives for a solution* activities | n/a | Economic perspective |
| Eval 2 | Ex-ante | Design | No dedicated evaluation activity mentioned; Evaluation of the results from the design part of the *design and development* activity | n/a | n/a |
| Eval 3 | Ex-post | Construction | Demonstration | Proof-of-concept (prototyping) | Engineering perspective |
| Eval 4 | Ex-post | Use | Evaluation | Proof-by-demonstration | Deployment perspective |

What do we mean by coherence between evaluation activities? We mean that the evaluated perspectives of the DSR process are logically connected and internally consistent. This allows designers to test certain attributes or components of the artifact where they are encountered first in the overall DSR process, instead of having to wait for the final evaluation activity (Eval 4). When designers can expect coherence between evaluation activities, they can also expect that evaluated intermediate design products lead to a useful final artifact. In cases of negative evaluation results, they only need to trace back to the preceding design activity, instead of the beginning of the overall design process. For example, when a prototype fails, designers only need to iterate back to the construction activity, but not to the design specification when they can assume coherence between the Eval 2 and Eval 3 activities.

The Eval 1 activity (evaluation of the *problem definition*) is concerned with justifying the relevance of the addressed problem. In DSR, scholars strive to demonstrate that "the envisioned design science research project is important for practice" (Sonnenberg and vom Brocke 2012b, p. 394). However, the underlying notion of relevance or what is meant by adjectives like "relevant" or "important" in a DSR project is rarely explicated. In management science, three forms of relevance are distinguished by Nicolai and Seidl (2010): instrumental, conceptual, and legitimative relevance. Instrumental relevance means building artifacts that can be used by practitioners ("instrumented") to solve problems in organizations. Conceptual relevance includes the uncovering of causal relationships or the definition of linguistic constructs: rather than prescribing specific courses of action, the practitioners' understanding of the decision situation is enhanced. Legitimative relevance provides rhetoric devices to help managers gain legitimacy and credibility when addressing their organizations. At this stage of our research, we cannot claim one notion of relevance to be preferable in a DSR project over another. We argue, however, that DSR researchers should clearly define which notion of relevance they are planning to achieve. Depending on the selected notion of relevance, different research methods are applicable in the Eval 1 and Eval 4 activities. In the Eval 1 activity, field research methods like expert interviews and focus groups may be more appropriate when aiming at instrumental relevance, whereas desk research methods like literature reviews or deductive reasoning may be more suitable when aiming at conceptual relevance. In the Eval 4 activity, researchers should assess whether an artifact solves a specific problem (instrumental relevance) or contributes to a better understanding of the decision situation (conceptual relevance). For example, expert interviews are a suitable evaluation method for both notions of relevance, but would need to involve different sets of questions. Summarizing, DSR researchers should stick to their initially selected notion of relevance when evaluating the final artifact in the Eval 4 activity.

In the Eval 2 activity, concerning the evaluation of the *design specification*, researchers should leverage the existing knowledge base and document their rationales for including particular kernel or design theories. This results in a design specification that builds on evaluated knowledge and may also lead to increased efficiency due to re-use (Gehlert et al. 2009). The challenge of evaluating the design specification (Eval 2) is exacerbated by the fact that many artifacts in the IS domain contain a significant social component. Long-term effects must be observed, where the ends are achieved long after the means have been applied. Thus, formal proofs or simulations may not be feasible for evaluating a design specification. Those methods only address the technological aspects of a solution. Instead, the duality of technological and social aspects should also be mirrored in the creation and evaluation of the design specification. Kernel theories that provide a link between technological artifacts and their adoption in social contexts, like the technology acceptance model (Davis 1989; Venkatesh and Davis 2000; Venkatesh et al. 2003), may be useful when creating a design specification. Such a design specification may be created using desk research methods like literature reviews to collect requirements and then be evaluated against field data (which may inform the researchers whether important requirements for the solution are missing). Moreover, researchers should also attempt to identify different situations. A design specification that takes different situations into account and formulates different sets of requirements towards the artifact depending on the situation is more likely to lead to a design that fits its specific use cases. Yet, defining situations is a challenging task in many domains (e.g., software engineering). Possible approaches to differentiate situations include national (Barrett and Oborn 2010; Jaakkola et al. 2010) or organizational culture (Aier 2014; Iivari and Huisman 2007).

After a prototypical instantiation of the artifact has been created in the *construct* activity, it should be demonstrated (Eval 3). Lab research methods like experiments are suitable for this evaluation activity, since researchers can assess their artifact in some of the three realities proposed by Sun and Kantor (2006), while surrogating the others by proxies. Thus, a resource-efficient evaluation can be done when a prototype is ready (e.g., many experiments involve students as proxies for real users when demonstrating an artifact), without having to wait for a full deployment into the real world. While this clearly represents a limitation, it nevertheless provides researchers an opportunity to test a "real system" with proxy users in a proxy setting (Mettler et al. 2014).

For the final evaluation activity (Eval 4), the artifact needs to be deployed in the real world, though, and be *used* by real users to conduct real tasks. The result of this evaluation activity shows the artifact's performance (i.e., the design product) in a given situation. Field research methods like case studies seem suitable for this activity, as they allow for the observation of complex effects. When designing a case study to evaluate an artifact, design science researchers should also revisit the notion of relevance they aim at (Nicolai and Seidl 2010). For example, conceptual relevance is attributed with better decision-making by providing linguistic constructs and uncovering hitherto unknown causal relationships. By interviewing decision makers, design science researchers may assess the conceptual relevance of their artifact (which would be given if the artifact contributed to better-informed decision making). Claiming instrumental relevance would potentially require researchers to observe the impact of their artifact on its environment over a sufficient time frame. Thereby, design science researchers can assess whether their artifact gives prospective users a means to reach their desired ends (this may be particularly challenging when effects do not occur immediately, but with some delay).

## F.4 Prototypical application of the feedback loops

We now provide an example of a coherent DSR feedback cycle using an actual DSR project we are involved in. This project has recently undergone the Eval 3 activity, and we are now preparing the Eval 4 activity. The problem we identified is the generation of shared understanding in enterprise transformation (ET), i.e., fundamental, non-continuous change in organizations. Shared understanding among diverse communities of practice (e.g., line managers, project managers, or enterprise architects) on the goals and plans of an ET is considered a key success factor (Bisel and Barge 2010; Elving 2005; Ford and Ford 1995; Stensaker et al. 2008). Enterprise architecture (EA) is a promising approach to foster shared understanding in ET (Asfaw et al. 2009; Labusch and Winter 2013; Simon et al. 2013). EA provides models on current (as-is) and future (to-be) enterprise states on a high level of abstraction by modeling the interplay of business processes and supporting software systems (Aier and Saat 2011). While EA models have the potential to be used across different communities of practice, the adoption of EA models for communication in ET is still low (Asfaw et al. 2009). One way to address this challenge is to consider and design EA models as boundary objects

(Valorinta 2011). Boundary objects (Star and Griesemer 1989) are abstract or physical artifacts that help to form a shared understanding among diverse communities of practice. They provide a platform for cooperative action, but without requiring the involved communities of practice to "abandon the distinctive perspectives, positions, and practices of their 'base' social world" (Winter and Butler 2011, p. 103).

Hence, the envisioned artifact is a set of design principles for constructing EA models as boundary objects. In this DSR project, we strive at both conceptual and instrumental relevance. We identify a lack of shared understanding between diverse communities of practice in enterprise transformation as a critical business problem. We offer the notion of boundary objects to describe artifacts—conceptual models from the EA domain—that help diverse communities of practice to achieve a shared understanding. By introducing the boundary object notion to the EA domain, we aim at conceptual relevance by providing a linguistic construct. Since our envisioned artifacts are design principles for the construction of boundary objects, we also aim at instrumental relevance by giving practitioners a means to shape organizational reality towards a desired end (turning an EA model into a boundary object and thereby foster shared understanding). To assess the conceptual relevance in the Eval 1 activity, we analyze the literature on both organizational change and EA, and arrive at the notion of boundary objects as a bridge between these two worlds. To assess the instrumental relevance, we conduct a series of expert interviews (Ghauri and Grønhaug 2010) to gather information on an ongoing transformation project in the air traffic management industry.

To obtain a design specification, we perform a structured literature review (Webster and Watson 2002) to identify a set of boundary object properties. We additionally conduct a focus group with enterprise architects to collect additional properties (Tremblay et al. 2010), since EA models are a prominent example of boundary objects (Pareto et al. 2010; Valorinta 2011). In the Eval 2 activity, we evaluate this design specification empirically by conducting a series of twelve expert interviews and a survey. We formulate some hypotheses describing different situations: we use the construct of knowledge boundaries to distinguish three situations of increasing distance among communities of practice (distance in terms of knowledge, values, and goals). Based on these situations, we analyze which properties from the initial set are required in which situation. Thus, we are able to perform an ex ante demonstration (Sonnenberg and vom Brocke 2012b) of the artifact: we expect a boundary object with a specific set of features to work in a specific situation. The problem we identified for our DSR project also serves as an example how deeply connected technological and social issues are in many IS research projects: in order to become a boundary object and obtain instrumental relevance for generating shared understanding, an object must not only possess certain constructional properties, but it must also be accepted and adopted by the involved communities of practice (Levina and Vaast 2005).

In the construction activity, we formulate some principles to implement a specific property ("visualization"). We reference the existing literature in the conceptual modelling field and the DSR knowledge base (specifically, the physics of notations design theory (Moody 2009)) when formulating our principles. In the demonstration activity (Eval 3), we test a subset of our artifact (principles on visualization) in an experimental setting: we describe an illustrative transformation setting (a merger of two telecommunication providers) and provide a fictitious capability model. We teach our visualization principles to doctoral candidates in the EA field. Finally, our subjects employ these principles to the fictitious model and comment on the feasibility of the principles for turning the capability map into a boundary object. In this activity, we have demonstrated a chunk of the artifact (i.e., the principles on visualization) to proxy users (i.e., students acting as proxies for enterprise architects) in a proxy setting (i.e., a fictitious model in a fictitious transformation setting). Thus, we test a part of our artifact in one of the three realities ("real systems") and approximate the remaining two ("real tasks, real users") (Sun and Kantor 2006).

The next step in our DSR project is the Eval 4 activity. We would need to deploy a complete instance of our artifacts (i.e., all our principles) in a real world setting: an organization conducting a real enterprise transformation would need to apply our design principles to one of their EA models. This model would then have to be used by members from diverse communities of practice and help them to form a shared understanding on the enterprise transformation goals and plans. A possible research method would be a single case study (Yin 2009): the unit of analysis would be a single boundary object that would have to be constructed and managed based on our design principles. By obtaining interview partners from different communities of practice (purposeful sampling strategy), the effect of the boundary object on achieving shared understanding could be observed. We can thus assess both the conceptual and the instrumental relevance of our artifact. Another reason for doing a case study in the Eval 4 activity (versus an experiment in the Eval 3 activity) is the time factor: when all three realities have to be observed to evaluate our artifact, this can only be done over an extended time period (Levina and Vaast 2005).

## F.5 Discussion

In this paper, we propose a DSR feedback cycle that does not only evaluate a DSR project from multiple perspectives, but also ensures coherence between these perspectives. We argue for ensuring coherence between the different evaluation activities by defining the notion of relevance in the problem definition activity. Based on this definition, we may then choose appropriate methods for the Eval 1 activity. The notion of relevance must also be revisited in the Eval 4 activity, when the final design product is evaluated in the real world. In other words, the Eval 1 and Eval 4 activities become coherent when the same concept of relevance is evaluated. We also argue for ensuring coherence between the design specification and prototypical instantiations. Via the definition of situations in the design specification, and prototypical instantiations of the artifact in these situations, coherence between the Eval 2 and Eval 3 activities can be achieved. By ensuring coherence between ex ante and ex post evaluation activities, DSR projects can overcome the initially stated drawbacks associated with performing an ex post evaluation only.

Revisiting the notion of "evaluation", this term might be reserved for the Eval 4 and Eval 3 activities: there, the artifact is evaluated in the real world, or demonstrated in a subset of the three realities. The ex ante activities Eval 1 and Eval 2 might possibly be called Valid 1 and Valid 2: validating a problem definition against a certain notion of relevance, and validating a design specification against certain situations (ex ante validation). Note that these activities do not involve any of the three realities. Evaluation would then arguably describe the evaluation of the design product (the artifact) in some of the three realities (Eval 3), and possibly the evaluation of the artifact in all three realities (Eval 4). A process that is reliable, reproducible, and efficient in leading to an evaluated artifact could then be called a validated design process.

## F.6 Research agenda and conclusion

Our work is *research-in-progress.* It contains several limitations, from which a research agenda can be derived. A major limitation in the cycle presented in this paper is that it does not explicate the often differing levels of abstraction of a problem description (Identify problem/Eval 1), respective solution components (Design/Eval 2), and the artefact and its instance itself (Construct/Eval 3 and Use/Eval 4). Generalizability often bears a statistically-oriented connotation (i.e., generalizing from empirical observations to underlying theory). However, in IS, other forms of generalizing have been suggested (Lee and Baskerville 2003; Lee and Baskerville 2012; Tsang and Williams 2012). This wider conceptualization of generalizability is explicitly considered to extend beyond "statistical and positivist research" and hence to be compatible with qualitative, interpretive, and design science research (Lee and Baskerville 2012, p. 759). In the following, we build on this wider conceptualization of generalizability to structure a research agenda on coherent evaluation activities in DSR. This research agenda consists of the following areas we consider to be fruitful for further research (Kuhn 1977, p. 321).

(1) Investigate additional evaluation activities before Eval 1 and after 4. An Eval 0 activity should evaluate the specialization of a generic problem class into the specific problem to be solved by the proposed artifact. An Eval 5 activity should, vice-versa, evaluate the generalization of a solution from a specific problem to a generic problem class. Depending on the artifact type, different notions of generalizability (Lee and Baskerville 2003, p. 233) are applicable. For example, when empirically derived principles are applied in another field, this implies a generalization from data to description. When a design theory is applied in another field (i.e., when its scope is extended), this implies a generalization from theory to description. Both examples represent an *exaptation* type of DSR knowledge contribution ("extend known solutions to new problems" (Gregor and Hevner 2013, p. 345)). Of particular interest are polar sampling strategies (Eisenhardt 1989; Eisenhardt and Graebner 2007), i.e., striving to increase the heterogeneity of application fields. Thus, the artifact's range of applicability, its usefulness, robustness, and eventually the users' trust in the artifact's utility can be increased.

(2) Check the transferability of the conceptual, instrumental, and legitimative notions of relevance from management science to IS DSR. This can be approached by researching which notions are applicable to which artifact types. For example, instrumental relevance can be associated with artifact types like methods, principles, or design theories, whereas conceptual relevance can be associated with descriptive artifact types like taxonomies or classification schemes. Nicolai and Seidl (2010) also suggest a trade-off relationship between instrumental and conceptual relevance. Investigating whether this is also the case in IS DSR and whether it is only associated with a certain notion of generalizability or certain artifact types, is another potentially fruitful research avenue.

(3) Ensure coherence between the Eval 2 and Eval 3 activities via situational design specifications. A generalized design specification can be transformed into a situational

design specification and then instantiated in a prototype. To identify how coherence between Eval 2 and Eval 3 activities has been achieved in other studies, a literature review on DSR projects in IS and related fields like computer science or management can provide important insights. To examine different situations in artifact design, high-level concepts like organizational culture are promising. For example, Aier (2014) proposes culture-specific approaches for designing and managing EA principles using the competing values model (Denison and Spreitzer 1991). Also, the number of intermediate levels required between a generalized design specification and a specific artifact (Winter 2012) instance should be an area of future research.

(4) Identify types of failure and revisit design activities in past DSR projects. For example, which kind of failures led to revisiting which previous design steps? Did failure in the construct activity lead to revisiting only the design activity, or has the root cause been an insufficient problem description? However, data collection may be difficult, since negative results often do not get published due to publication bias (Hunter and Schmidt 1990).

(5) Incorporate affordances into a generalized design specification. Originating from perceptual psychology (Norman 1999), affordances describe properties of things that are obvious, readily available and intuitive, so that they do not require further explanation or training (e.g., the handle of a tea cup). Solution properties with affordance character would not need to be evaluated on instance level, but could (much more efficiently) be validated as part of a generalized design specification. Research on national culture can provide important insights, since affordances are likely to vary between national cultures. Affordances are a potential avenue for researching the distinction between validation and evaluation in the DSR (Gregor and Hevner 2013).

(6) Integrate with DSR process models. To increase the penetration in research and practice, the discussed evaluation perspectives should be incorporated into popular DSR process models (e.g., the DSR methodology process model (Peffers et al. 2007)).

In this research-in-progress paper, we argue for coherence between different DSR evaluation perspectives by explicating the underlying notion of relevance and by using situational design specifications. We identify fruitful areas for further research (research agenda). In particular, we call for an investigation into the different forms of generalizability in DSR design and evaluation activities.

*Acknowledgement*

This work has been supported by the Swiss National Science Foundation (SNSF).

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# Curriculum vitae

## Personal information

| | |
|---|---|
| Name | Ralf Abraham |
| Date of birth | 24.11.1982 |
| Place of birth | Nuremberg, Germany |
| Nationality | German |

## Education

| | |
|---|---|
| 2011-2015 | University of St. Gallen, St. Gallen, Switzerland<br>Ph.D. programme in management (Business Innovation) |
| 2002-2008 | University of Erlangen-Nürnberg, Nürnberg, Germany<br>Diploma programme in Wirtschaftsinformatik |
| 1993-2002 | Heinrich-Schliemann-Gymnasium, Fürth, Germany<br>A Levels |

## Professional experience

| | |
|---|---|
| 2011-2015 | University of St. Gallen, Institute of Information Management, Chair of Prof. Dr. Robert Winter, Switzerland<br>Research associate |
| 2009-2011 | Siemens AG, Industry sector, Germany<br>Software developer |
| 2009-2011 | Friedrich-Alexander-Universität Erlangen-Nürnberg, Chair of Wirtschaftsinformatik III (IT-Management), Germany<br>Student assistant |