

Revisiting the Impact of Information Systems Architecture Complexity: A Complex Adaptive Systems Perspective

Completed Research Paper

Raphael David Schilling

Institute of Information Management
University of St. Gallen
St. Gallen, Switzerland
raphael.schilling@unisg.ch

Jannis Beese

Institute of Information Management
University of St. Gallen
St. Gallen, Switzerland
jannis.beese@unisg.ch

M. Kazem Haki

Institute of Information Management
University of St. Gallen
St. Gallen, Switzerland
kazem.haki@unisg.ch

Stephan Aier

Institute of Information Management
University of St. Gallen
St. Gallen, Switzerland
stephan.aier@unisg.ch

Robert Winter

Institute of Information Management
University of St. Gallen
St. Gallen, Switzerland
robert.winter@unisg.ch

Abstract

Organizations constantly adapt their Information Systems (IS) architecture to reflect changes in their environment. In general, such adaptations steadily increase the complexity of their IS architecture, thereby negatively impacting IS efficiency and IS flexibility. Based on a Complex Adaptive Systems (CAS) perspective, we present a more differentiated analysis of the impact of IS architecture complexity. We hypothesize the relation between IS architecture complexity on the one hand, and IS efficiency and IS flexibility on the other hand to be mediated by evolutionary and revolutionary IS change. Subsequently, we test our hypotheses through a partial least squares (PLS) approach to structural equation modelling (SEM) based on survey data from 185 respondents. We find that the direct negative impact of IS architecture complexity on IS efficiency and IS flexibility is no longer statistically relevant when also considering the mediating effects of revolutionary and evolutionary IS change.

Keywords: Information System Architecture, Complex Adaptive Systems, Evolutionary IS Change, Revolutionary IS Change, IS Efficiency, IS Flexibility

Introduction

The ability to quickly adapt an organization's Information Systems (IS) to the changing business environment is a widely acknowledged enabler of an organization's competitive advantage (Orlikowski 1996). Consequently, IS management does not only need to align IS support with current business requirements, but also to ensure IS adaptability to the emerging business requirements. One of the prevailing disciplines in the IS literature to deal with such challenge is the systematic planning and steering of *IS architecture* (Richardson et al. 1990; Schmidt and Buxmann 2011; Zachman 1987). IS architecture represents the actual and envisioned component structure of an organization's IS as well as their interrelations and the principles that guide IS design and evolution (ISO/IEC/IEEE 2011). Through continuously redesigning and maintaining their IS architecture, organizations ultimately aim to achieve advantageous *IS architecture outcomes*, in particular *IS flexibility* (i.e., the ability to adapt to environmental changes in a fast, resource-saving manner) as well as *IS efficiency* (i.e., an optimized ratio between IS-related capabilities and required resources) (Schmidt and Buxmann 2011).

Over the last decades, the scope of IS architecture grew from controlling small scale systems towards managing multinational corporations and global ecosystems (Bernus et al. 2016; Mocker 2009). In turn, IS have become complex socio-technical systems, which can no longer be described by a single model or entirely controlled through central means (Bernus et al. 2016). Dealing with complexity is thus considered to be one of the grand challenges in IS architecture (Bernus et al. 2016). IS research may address this challenge by explaining causes and effects within such complex IS. Thus, our research question is:

RQ: How does IS architecture complexity affect IS flexibility and IS efficiency?

Earlier studies mostly highlight the negative consequences of IS architecture complexity on IS architecture's expected outcomes in terms of increased coordination efforts, higher failure rates of large implementation projects, or lower IS flexibility (e.g., Beetz and Kolbe 2011; Hanseth and Bygstad 2012; Widjaja et al. 2012). We complement this research by employing a *complex adaptive systems (CAS)* perspective to account for the complex and adaptive character of IS architecture (Anderson 1999; Cohen and Axelrod 1999). Originating in complexity science, CAS has been described to be a suitable theoretical lens to analyze the emergence of order in complex socio-technical systems as a result of individual actions (Anderson 1999).

Building on the theoretical premises of CAS and in seeking to answer our research question, we derive a research model that conceptualizes the impact of IS architecture complexity on its expected outcomes and that considers both revolutionary and evolutionary adaptive changes in IS architecture. By doing, so we reflect "design incompleteness" (Cherns 1987) as an inherent aspect of such complex systems, i.e., the continuous need to review and revise IS architecture (Beese et al. 2015). We test the derived research model based on data from 185 respondents through a partial least squares approach (PLS) to structural equation modelling (SEM).

Our results confirm the direct negative impact of IS architecture complexity on expected architectural outcomes (i.e., IS efficiency and IS flexibility). However, we also find that IS architecture complexity is positively related with revolutionary and evolutionary IS change, and that evolutionary IS change has a positive impact on IS architecture outcomes. In turn, the direct negative relation between IS architecture complexity and the expected architectural outcomes is no longer statistically relevant when additionally considering the mediating effects of revolutionary and evolutionary IS change. Through the proposed model, we thus explain how expected outcomes of IS architecture can be achieved through the adaptive behavior of IS architecture and its co-evolution of organizational and technological aspects.

Following this introduction, we first review related work on the effects of IS architecture complexity. We then develop the theoretical foundation of this work and derive specific hypotheses, before presenting and discussing our results.

Related Work

Early research efforts on IS architecture mainly focused on the design of prescriptive architecture artifacts, such as frameworks, methods, and models, that support the development and maintenance of IS architecture (Lankhorst et al. 2004; Sowa and Zachman 1992; Zachman 1987). Notwithstanding the initial effort in developing such architecture artifacts, many organizations struggle in adequately deploying IS

architecture methods and frameworks (Roeleven and Broer 2009; Schmidt and Buxmann 2011). Therefore, scholars moved their research focus toward the measures and outcomes of IS architecture (Lange et al. 2016; Schmidt and Buxmann 2011; Tamm et al. 2011). One of the predominant factors that hinder the success of IS architecture endeavors, is the complexity of IS architecture, which results from the engagement of diverse organizational and technological stakeholders (e.g., business units, developers, architects) as well as rapid changes in both the organizational and the technological environments (Mocker 2009; Schütz et al. 2013a). Arguably, most IS architectures meet the criteria of complex systems proposed by Page (2009) where agents (systems, users, etc.) show a certain level of diversity, are connected, interdependent, and adapt through learning processes. Several recent studies hence focus on IS architecture complexity (e.g., Beese et al. 2016; Mocker 2009; Schneider et al. 2015; Schütz et al. 2013b), making it one of the major topics in the growing discipline of IS architecture. In the following, we briefly review how IS architecture complexity has been examined and to which degree the effects of IS architecture complexity have been discussed.

IS Architecture Complexity: Owing to its socio-technical nature, existing research discusses IS architecture from both organizational and technical perspectives. Concerning the technical perspective, extant studies describe IS architecture complexity by considering the application architecture (e.g., interdependencies and redundancies among applications) as well as the infrastructure architecture (e.g., IT landscape size, technological diversity) (Beetz and Kolbe 2011; Dern and Jung 2009). Mocker (2009) as well as Aletrati et al., (2016), for instance, focus on different aspects of application architecture complexity (e.g., interdependency, diversity, deviation, overlap) and evaluate the causes and consequences of this complexity.

The organizational perspective on IS architecture complexity is less evident in the existing research. Widjaja et al. (2012) propose means to quantify and compare the heterogeneity of IT landscapes in organizational units. In addition to technical aspects, such as the heterogeneity of semantics in databases, they find that organizational aspects, such as the number of software vendors should be considered when analyzing the heterogeneity of the IT landscape (Widjaja et al. 2012).

Effects of IS Architecture Complexity: Besides studies on causes and drivers of IS architecture complexity, the effects of IS architecture complexity have also been the focus of research (Beese et al. 2016; Beetz and Kolbe 2011; Hanseth and Bygstad 2012; Mocker 2009; Widjaja et al. 2012). These studies all observe negative consequences and effects of IS architecture complexity, such as a reduction in IS flexibility, or hindering innovation activities (Widjaja et al. 2012). IS architecture complexity has also been associated with higher failure rates of large implementation projects (Hanseth and Bygstad 2012). Furthermore, research concluded that IS architecture complexity would lead to higher coordination efforts (Hanseth and Bygstad 2012).

However, existing research on the negative consequences of IS architecture complexity often conceptualizes IS architecture complexity by simply counting objects (e.g., applications, or interfaces) and then conducting correlation analyses (e.g., Aletrati Khosroshahi et al. 2016; Mocker 2009). Consequently, such studies do not account for complexity as an inherent, dynamically evolving property of IS architecture (Vessey and Ward 2013). Such analysis requires a careful inclusion of the complex adaptive systems (CAS) perspective in the investigation of expected outcomes of IS architecture, which is the motivation for our research.

Theoretical Foundation and Hypotheses Derivation

Since IS architecture is a socio-technical phenomenon, its complexity arises and evolves through dialectical interactions between organizational and technological aspects (Lyytinen and Newman 2008). Therefore, IS architecture can be considered as a continuous effort to keep changing organizational aspects aligned with changing technological aspects (Boh and Yellin 2006; Ross 2003; Simon et al. 2013). This dialectic eventually results in both evolutionary IS change, aimed at fixing misalignment between organizational and technological aspects, as well as revolutionary IS change, aimed at re-configuring the way organizational and technological aspects are interlinked (Lyytinen and Newman 2008).

In the literature, IS architecture has been predominantly viewed from a deterministic vantage point that enforces some ideal, pre-defined configuration. In contrast, a few recent studies take a distinctive approach that describes the evolution of IS architecture as a non-linear, and consequently a non-deterministic

process (Haki and Legner 2013). In line with the latter perspective, we examine IS architecture through the theoretical lens of complex adaptive systems (CAS) (Axelrod 1984; Holland 1995).

Originating in complexity science, CAS are supportive in analyzing how order as a result of individual actions emerges in complex systems (Anderson 1999). The CAS perspective describes a complex system, such as IS architecture, as a “dynamic network of interdependent, interacting agents (e.g., cells, species, individuals, firms, and nations) bonded by common goals, views, and needs that act in parallel, and that constantly act and react to the actions of other agents” (Vessey and Ward 2013, p. 284). In such systems, complexity arises due to the high number of involved actors, which constantly need to adjust and adapt to each other (Vidgen and Wang 2009).

IS scholars have applied the CAS perspective to model the interactions and relationships of agents on a microscopic level in order to analyze their contribution on the macroscopic level (Nan 2011). By doing so, they could focus on the individual agents without having a need for a holistic understanding of the complex system upfront. CAS models thus offer “exciting new opportunities for analyzing complex systems without abstracting away their interdependencies and nonlinear interactions” (Anderson 1999, p. 220). In addition, the CAS perspective has, for example, been applied to understand the adaptive behavior of the interacting actors (Morel and Ramanujam 1999), to explain IT usage from a bottom-up perspective (e.g., Curşeu 2006; Nan 2011), to analyze open source systems (Link and Germonprez 2016; Muffato and Faldani 2003) and—more generally—to understand how order emerges between co-evolving systems (Kim and Kaplan 2006). More closely related to the IS architecture discipline, CAS has also been applied to the concept of business-IT alignment (e.g., Benbya and M. McKelvey 2006; Tanriverdi et al. 2010; Vessey and Ward 2013).

IS Architecture as a Complex Adaptive System

The three *principles of coevolving, self-renewing organizations* proposed by Volberda and Lewin (2003), provide a suitable framework for capturing the key concepts of CAS (i.e., coevolution, interconnected autonomous agents, self-organization) (Vidgen and Wang 2009, p. 357). They have previously been used to examine adaptive IS management (e.g., Luse and Mennecke 2014; Vessey and Ward 2013) and also provide a lens to analyze the adaptive behavior of IS architecture. In the following we introduce these three principles and their relation to IS architecture as a CAS.

Principle I: CAS co-evolve with the change rates of their environment: Typically, CAS are embedded in an ecosystem where different systems co-evolve, meaning that they reciprocally affect each other's evolution (Vidgen and Wang 2009). To be capable to respond to changes in the environment, CAS need to ascertain requisite variety (Ashby 1956), i.e., to maintain internal rates of change that are equal or exceed the external rate of changes (McKelvey 2003). CAS thus develop “routines, capabilities, and measures which monitor and track rates of change in all aspects of their environment” (Volberda and Lewin 2003, p. 2126). For IS architecture this implies that they will constantly tend to adapt to changes in the organizational and technological environment (e.g., changed market requirements or new technologies). Accordingly, considering the constant increases in connectivity, capacity for data processing, and range of information transmission, Merali concludes: “The increase in the number of components to be integrated across diverse technological platforms and business systems demands complex architectures” (Merali 2006, p. 217).

Principle II: In CAS, autonomous agents are interconnected: In CAS, agents organize themselves and take decisions based on their perception of the environment. By delegating decision making to the lowest possible level, CAS are capable to find order even in complex environments (Volberda and Lewin 2003). The agents and their interactions are thereby guided through commonly agreed values and boundary conditions in combination with process- rather than outcome-control mechanisms (Volberda and Lewin 2003). This allows the agents to react faster in response to changes in their close environment and avoids information overflow (Vidgen and Wang 2009). In line with this conception is the recent call for more influence based rather than control based approaches in IS architecture management, envisioning a changed behavior of local decision makers (e.g., project teams) (Winter 2016).

Principle III: In CAS, concurrent exploitation and exploration are synchronized: In order to ensure the long-term survival of the system, CAS balance between efforts required for the future viability (i.e., innovation, exploration), and efforts required for maintaining the current viability (i.e., improvement, exploitation) (Volberda and Lewin 2003). To achieve the expected outcomes and to deal with environmental changes, IS architecture have been described to evolve in successive phases of evolutionary

(exploitation) and revolutionary (exploration) changes (Lyytinen and Newman 2008). While the continuous adjustment of the IS architecture of an organization ensures operational efficiency (exploitation), fundamental changes to the IT strategy are required to ensure the long-term survival of the organization (exploration).

Hypothesis Development

Our research model and its constituent hypotheses (see Figure 1) are based on the assumption that IS architecture can be considered as a CAS, behaving according to the principles of coevolving, self-renewing organizations (Volberda and Lewin 2003). The research model tests the effect of IS architecture complexity (i.e., structural and dynamic complexity in the technological and organizational environment) on IS architecture outcomes (i.e., IS flexibility and IS efficiency), while simultaneously considering adaptive revolutionary and evolutionary IS change (i.e., concurrent exploration and exploitation).

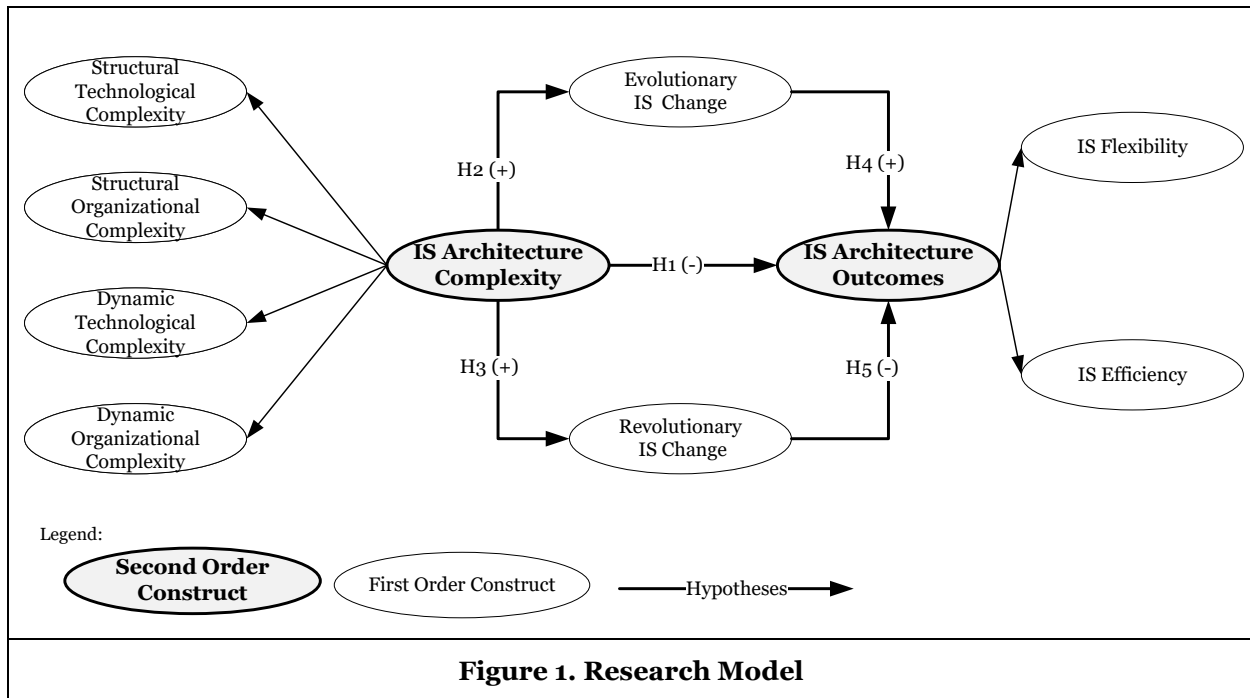


Figure 1. Research Model

Morel and Ramanujam (1999) characterize complex systems through their large number of interacting elements in combination with emerging properties. In line with this perception, we adopt the concept of IS development project complexity proposed by Xia and Lee (2005) and consider IS architecture complexity to consist of a structural and dynamic part in both, an organizational and technological environment. This IS architecture complexity will affect the *IS architecture outcomes*, which we reflect by following Schmidt and Buxmann (2011) in terms of both *IS flexibility* and *IS efficiency*. *IS flexibility* is concerned with the ability to adapt to environmental changes in a fast, resource-saving manner. A loss in IS flexibility—due to a complex IS architecture that comprises many components and interdependencies—reduces the system’s ability to react to changes in the organizational environment and hence leads to higher costs and time to market. *IS efficiency*, in turn, reflects the relation between the capabilities of IS (e.g., automation, integration) and the required resources (e.g., budget and human resources) to provide such capabilities. For example, a complex IS architecture with a high number of interfaces leads to higher maintenance and operating costs (Schmidt and Buxmann 2011). In line with previous studies (Beese et al. 2016; Mocker 2009), we therefore assume:

H1: IS architecture complexity is negatively related to IS architecture outcomes.

According to principle I of coevolving, self-renewing organizations, IS architectures will evolve with the change rates of their environment. Changes in the organizational and technological environments (e.g., changed market requirements, new technologies) entail that the IS architecture changes and adapts in line with these new requirements to achieve the expected outcomes. This change process can be distinguished

along scope (convergent versus radical) and pace (evolutionary versus revolutionary) (Greenwood and Hinings 1996). Accordingly, two major change paradigms are distinguished. The first change paradigm is incremental in nature, where evolution is seen as an outcome of small adjustments of organisms to the environment (Gersick 1991). The second paradigm, the model of *punctuated change*, describes change as a process expressed by times of stability (equilibrium) as well as times of revolutionary change (punctuation) (Lyytinen and Newman 2008). Proponents of the punctuated change perspective (e.g., Lyytinen and Newman 2008; Sabherwal et al. 2001) describe change as “an alternation between long periods when stable infrastructures permit only incremental adaptations, and brief periods of revolutionary upheaval” (Gersick 1991, p. 10). From a complexity theory’s perspective, however, a punctuated equilibrium does not arise from inertia but rather from “a pattern over time of large and small changes” in a system of coevolving agents (Anderson 1999, p. 224). Therefore, exploitation and exploration are synchronized in CAS (principle III) and reflected through evolutionary and revolutionary change in our model. While in exploitation organizations optimize their current capabilities, exploration refers to the creation of new competencies. Exploitation is achieved through refinement, improvements in efficiency and standardization, i.e., activities that can be considered as evolutionary change (He and Wong 2004; March 1991; Matook et al. 2016). We thus posit:

H2: IS architecture complexity is positively related to evolutionary IS change.

Exploration, in turn, may result in the discovery of new technologies or products as well as in changes in the mode of working (Levinthal and March 1993). A change in the applied technologies or the mode of working entails a change in the system’s deep structure, reflecting a revolutionary change. Therefore, we hypothesize:

H3: IS architecture complexity is positively related to revolutionary IS change

Since these change activities lead to a change in the IS architecture, its expected outcomes would consequently be affected. A recent study proposes that IS architecture should be managed through evolutionary change and proposes the concept of “enterprise architecting” (Rolland et al. 2015). By doing so, path dependencies and the uncertainty of the future could be better managed in a “incremental step-by-step fashion” (Rolland et al. 2015, p. 12), that eventually leads to desirable IS architecture outcomes. In line with principle II, stating that complexity can be managed by constant interaction among IS architecture stakeholders, we thus posit:

H4: Evolutionary change is positively related to IS architecture outcomes.

Conversely, several studies have shown that revolutionary, large scope change is challenging because local units tend to be reluctant to change (e.g., Aanestad and Jensen 2011; Cohen and Levinthal 1990). In order to alter a systems fundamental choices, the “deep structure must first be dismantled, leaving the system temporarily disorganized, in order for any fundamental changes to be accomplished” (Gersick 1991, p. 19). There is a chance that the system fails in establishing a new deep structure and reverts back to the original structure or it may even “escalate into continued disarray where it oscillates between upheavals and attempts to bring order” (Lyytinen and Newman 2008, p. 593). Revolutionary change appears to be especially challenging in the case of complex and path dependent IS architectures: The case study described by Rolland et al. (2015) shows, that increased complexity makes architects “reluctant to radically change the architectures according to the visions because of unknown consequences“ (Rolland et al. 2015, p. 12) We therefore expect revolutionary change to have a negative effect on IS architecture outcomes from a short-term perspective:

H5: Revolutionary change is negatively related to IS architecture outcomes.

Research Method

We evaluate the derived hypotheses via a structural equation model (SEM) that is directly based on the research model described in Figure 1. We choose a partial least squares (PLS) approach to SEM over covariance-based approaches to reduce the risk of overfitting during analysis, since there is no well-established a-priori theory that integrates a CAS perspective with IS architecture complexity and corresponding outcomes (Gefen et al. 2011). In conducting and presenting our analysis, we follow the recommendations of Gefen et al. (2011) and Ringle et al. (2012). Hypothesis testing was performed using

SmartPLS version 3.2.6 (Ringle et al. 2015), additionally relying on R (version 3.3.3) for descriptive statistics.

Construct Operationalization

We operationalize the constructs by adapting existing scales identified in literature. While the overall model is supposed to reflect a CAS perspective on IS architecture, the individual constructs per se are only indirectly related to CAS. Table 1 provides a list of all measurement items included in the final model, including respective missing value percentages as well as factor loadings and t-values.

Table 1. Overview of Measurement Items					
Construct		Measurement item	Miss.	Ld.	t-val.
IS Architecture Complexity	SIT1	The IT systems of my company are highly interdependent.	0.5%	.78	10.97
	SIT2	The IT systems of my company are based on different technology platforms.	2.2%	.89	32.51
	SORG1	IT projects usually consist of persons from several functional areas.	0.0%	.78	2.10
	SORG2	IT projects usually have several internal business partners.	0.0%	.95	3.47
	DIT1	The technology of the IT project environment changes frequently.	0.0%	.88	52.06
	DIT2	The IT infrastructure of my company changes frequently.	0.0%	.89	29.74
	DIT3	The (software-) development methods applied in my company change frequently.	1.1%	.83	25.11
	DORG1	The business processes of my company change frequently.	1.1%	.86	26.11
	DORG2	The organizational structure of my company changes frequently.	0.0%	.88	41.90
Evolutionary IS Change	EC1	The employees of my company are regularly trained so that they can master their (changing) tasks.	0.0%	.72	16.35
	EC2	IT systems are continuously adjusted in order to reflect the organizational structures.	0.0%	.73	11.63
	EC3	The IT architecture of my company is continuously adjusted and modified in order to reflect organizational changes.	0.0%	.77	20.98
	EC4	For new tasks, adequate technological solutions are identified and timely implemented.	1.1%	.71	14.11
Revolutionary IS Change	RC1	Within the past few years, employees of the company had to take over completely new tasks and acquire new skills.	0.5%	.74	8.91
	RC2	Within the past few years, the organizational structures of my company have been fundamentally changed.	0.5%	.80	7.31
	RC3	Within the past few years, the IT strategy has fundamentally changed.	1.1%	.75	9.65
	RC4	Within the past few years, the technological basis of our IT architecture has fundamentally changed.	0.5%	.70	6.58

IS Architecture Outcomes	FLEX1	Interfaces are transparent and allow simple access for most applications.	0.0%	.80	29.42
	FLEX2	A unified view on the customers of my company is available to every authorized user.	2.2%	.68	13.25
	FLEX3	Customer requests for new functionalities can be quickly integrated into our applications.	1.1%	.87	56.26
	FLEX4	The business processes of my company can be rearranged without major changes in the system.	0.5%	.82	27.75
	EFF1	The IT services of my company are produced in a cost-effective way.	2.2%	.88	38.38
	EFF2	The overall IT costs of my company are lower compared to the competitors.	0.5%	.87	39.11

Miss. = missing value percentage, *Ld.* = factor loading, *T-Val* = t-values

IS Architecture Complexity: We adapt the proposed measures of IS development project complexity by Xia and Lee (2005) to reflect IS architecture complexity. We employ a total of nine items, two for Structural Technological Complexity (SIT, reflecting the interdependency of IT systems and the variety of the underlying technological platform), two for Structural Organizational Complexity (SORG, reflecting the diversity of stakeholders in projects), three for Dynamic Technological Complexity (DIT, reflecting the frequency of changes in the technological infrastructure and development methodologies), and two for Dynamic Organizational Complexity (DORG, reflecting the frequency of changes in the organizational structure and business processes).

IS Change: The eight items used to measure IS change are based on the models of Sabherwal et al. (2001) and Lyytinen and Newman (2008). We differentiate between revolutionary change (fundamental changes within the last few years, four items) and evolutionary changes (regular continuous adjustments, four items).

IS Architecture Outcomes: The six items to measure IS architecture outcomes are based on the model proposed by Schmidt and Buxmann (2011). Consequently, we distinguish between IS flexibility (ability to adapt to environmental changes in a fast, resource-saving manner, four items) and IS efficiency (optimized ratio between IS capabilities and required resources, two items). Compared to the original model, we do not further differentiate IT flexibility into connectivity, compatibility and modularity. Instead we model IT flexibility as a combination of compatibility and modularity.

To ensure comparability, all 23 items are measured at the organizational level on a 5-point Likert scale. Survey participants were asked to rate the extent to which they agree with the item statements for their organization, ranging from “strongly disagree” (1) to “strongly agree” (5). All constructs in the model are measured in a reflective, rather than formative mode, since the model’s measurement items do not represent a complete, exhaustive representation of the respective constructs, but instead are indicative of a certain construct being present in the organization of a responding participant.

Data Collection

We collected data from both an online survey and a paper-based survey. The paper-based survey was handed out at an European IS practitioner conference in November 2016. After the research project was introduced by one of the authors, we distributed questionnaires to all 92 participants of the conference, resulting in 81 filled out responses (88% response rate). We then used the same items in an online survey to collect additional data during December 2016. The online survey was sent to 332 contacts, leading to 104 additional responses (31% response rate). In total, we received 185 survey responses. For both surveys, we specifically targeted people with a relation to IS architecture, i.e., experienced senior enterprise architects and IT managers of large enterprises.

Data Analysis and Descriptive Statistics

To avoid common method bias, we compared responses from the online and the paper-based survey using Multi-Group-Analysis (MGA) (Hair Jr. et al. 2014; Rigdon et al. 2010). No significant differences were

found. We also visually inspected the survey responses and did not detect any outliers or unusual response patterns. Furthermore, at most two items were missing for any given respondent, thus allowing us to use all 185 responses in the analysis. Table 2 provides a demographic overview (industry, company size, and length of employment) of our data. We targeted our survey at experienced senior enterprise architects and IT managers in large enterprises, thus nearly 60% of our responses come from people working at organizations with more than 5000 employees and 75% of respondents have been employed by their current company for more than 6 years.

Industry	Percent	Company Size	Percent
Utilities	5.7	<50	5.0
Financial Services	29.9	50-249	7.2
Health care	1.7	250-999	5.5
Retail	1.1	1000-4999	22.7
Information and Communication	14.4	>5000	59.7
Public Administration	4.4	Length of Employment	
Manufacturing and Processing	8.6	< 2 years	6.1
Insurance	18.4	2-5 years	23.9
Transport and Logistics	9.2	6-10 years	25.2
Others	6.9	> 10 years	44.8

Missing values were handled through mean replacement and bootstrapping was conducted with a sample size of 5000 to assess the significance and predictive validity of our results.

Measurement Model and Validity Tests

Table 3 shows the number of items for each construct of the measurement model, as well as general scale information (mean and standard deviation) and standard statistical quality criteria (composite reliability, Cronbach's α , average variance extracted (AVE), and R^2 values).

	Items	Comp. Reliab.	Cronb. Alpha	AVE	R²	Mean	Std. Dev.
Structural Technological Complexity	2	0.820	0.571	0.696	0.375	4.013	0.814
Structural Organizational Complexity	2	0.861	0.713	0.758	0.135	3.983	0.771
Dynamic Technological Complexity	3	0.900	0.834	0.751	0.701	2.737	0.774
Dynamic Organizational Complexity	2	0.861	0.676	0.755	0.511	3.101	0.891
IS Architecture Complexity	9	0.808	0.734	0.340	-	3.414	0.534
Evolutionary IS Change	4	0.821	0.711	0.535	0.049	3.198	0.707

Revolutionary IS Change	4	0.835	0.742	0.558	0.128	3.342	0.815
IS Flexibility	4	0.872	0.862	0.632	0.851	2.713	0.811
IS Efficiency	2	0.866	0.804	0.763	0.699	2.910	0.914
IS Architecture Outcomes	6	0.874	0.690	0.539	0.278	2.720	0.759

Concerning construct reliability, the values for the composite reliability of the constructs (> 0.7) and for Cronbach’s α (> 0.7) are within acceptable ranges for the higher-level constructs that are used to test the hypotheses (Hair Jr. et al. 2014). Furthermore, Table 1 shows that almost all indicators (except FLEX2) have factor loadings above 0.7 (Hair Jr. et al. 2014) and are significant at the 0.01 level (t -value > 2.576 , except SORG1), thus ensuring high indicator reliability (i.e., the variance of an indicator is explained by the corresponding construct). Since the values for both SORG1 and FLEX2 are borderline, their descriptions are in line with the original sources, and their removal would not significantly increase the validity of the corresponding constructs, we decided to keep them in the final model. In addition, we separately tested the unidimensionality of all lower-level constructs by performing separate factor analyses, following Gefen (2003), and Gefen and Straub (2005). In all cases a single component was extracted, on which the items load evenly and which explains most of the variance.

Regarding discriminant validity, all constructs involved in hypothesis testing need to be sufficiently dissimilar (Gefen and Straub 2005). We thus tested the discriminant validity for all four constructs (IS Architecture Complexity, Revolutionary IS Change, Evolutionary IS Change, and IS Architecture Outcomes) using Heterotrait-Monotrait (HTMT) analysis (see Table 4). Resulting values are well within the threshold (< 0.9) recommended by Henseler et al. (2015).

Table 4. Heterotrait-Monotrait (HTMT) Analysis of Discriminant Validity

	IS Architecture Complexity	Revolutionary IS Change	Evolutionary IS Change
Revolutionary IS Change	0.461		
Evolutionary IS Change	0.389	0.338	
IS Architecture Outcomes	0.224	0.138	0.632

We additionally performed linear regression tests between connected constructs to ensure that the variance inflation factors (VIF) and Durbin-Watson statistics are within acceptable thresholds (Kutner et al. 2005), indicating no potential problems with collinearity.

Finally, we tested the predictive relevance of the model with the non-parametric Stone-Geisser test by applying a blindfolding procedure with an omission distance of 7 in SmartPLS (Hair Jr. et al. 2014). All Q^2 values (*IS Architecture Outcomes*: 0.13, *Evolutionary IS Change*: 0.02, *Revolutionary IS Change*: 0.06, *IS Flexibility*: 0.51, *IS Efficiency*: 0.50) are larger than zero (Hair Jr. et al. 2014). This indicates that the model has predictive validity, i.e., empirical data can be reconstructed using the model and the PLS parameters (Götz et al. 2010).

Results and Hypotheses Testing

Figure 2 shows the final SEM, capturing how IS architecture complexity affects IS Change and IS Architecture Outcomes. The arrows linking the constructs show the respective path coefficients (first number), the significance level estimates (***: $p < 0.01$, **: $p < 0.05$) from bootstrapping with 5000 samples, and the effect sizes (f^2 , second number in brackets). Path coefficients represent the standardized

weights of the linear regressions in the SEM approach, which, in combination with the effect sizes, allow to evaluate the relative effects in the fitted regression model (Hair Jr. et al. 2014). The constructs themselves include the determination coefficients (R^2), reflecting the share of an endogenous construct that is explained by the incoming links (Hair Jr. et al. 2014).

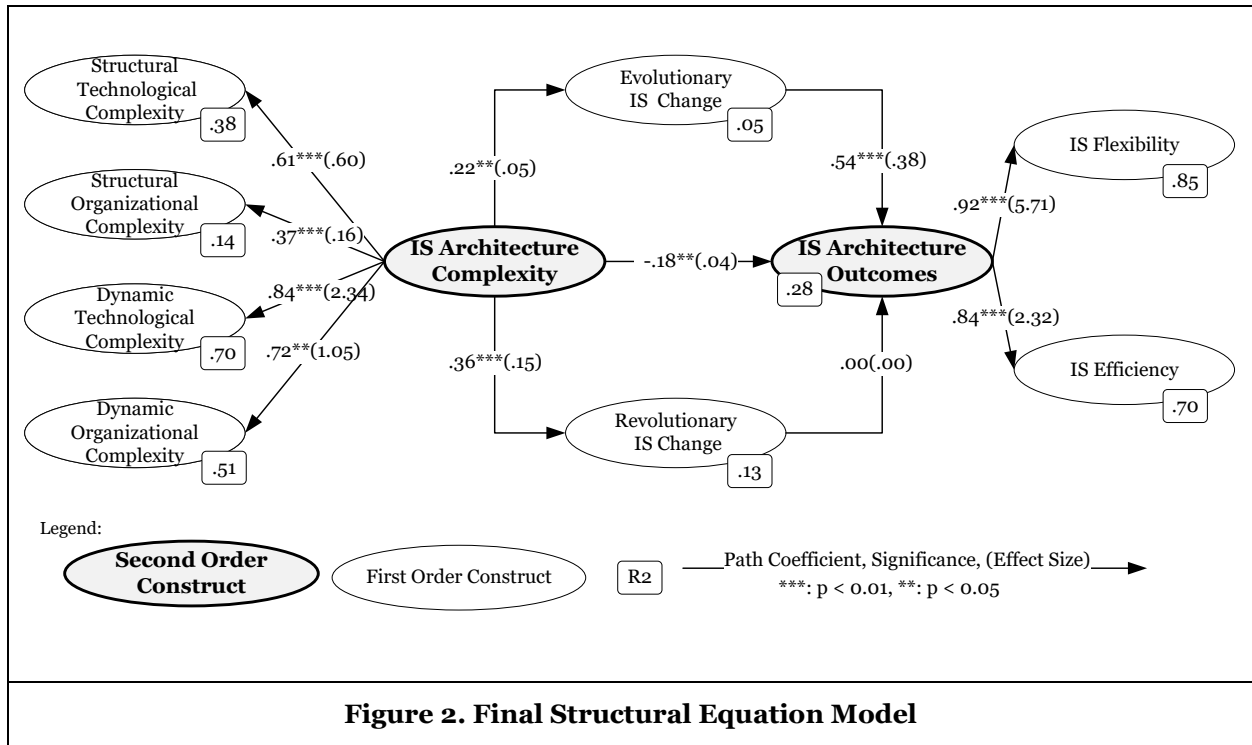


Figure 2. Final Structural Equation Model

In our structural model, IS architecture outcomes are both directly and indirectly (through evolutionary and revolutionary IS change) affected by IS architecture complexity. Consequently, our analysis is subject to mediation effects. As suggested by Hair et al. (2013), we therefore also report the total effects, i.e., the sum of direct and indirect effects between two constructs (Hair et al. 2013), and the corresponding results from bootstrapping analysis. Table 5 displays the total effects (f^2) and corresponding significance levels (***: $p < 0.01$, **: $p < 0.05$).

	Continuous IS Change	Revolutionary IS Change	IS Architecture Outcomes
IS Architecture Complexity	0.222**	0.358***	-0.065
Continuous IS Change			0.537***
Revolutionary IS Change			0.001

Compared to Figure 2, the major difference in Table 5 is that the significant negative link between IS architecture complexity and IS architecture outcomes ($p = 0.021 < 0.05$, **) is not significant anymore ($p = 0.503 > 0.1$, upper right cell of Table 5) when considering the additional mediation effects through the change constructs.

Testing of Hypotheses

We now evaluate our hypotheses based on the data in Figure 2; the results are summarized in Table 6. Complementing our analysis, we also critically evaluate H1, also considering the total effects in the structural model displayed in Table 5.

Hypothesis	Statement	Path coefficient and significance	t-value	Result
H1	IS Architecture Complexity → IS Architecture Outcomes	-0.184**	2.308	Supported
H2	IS Architecture Complexity → Evolutionary IS Change	0.222**	2.351	Supported
H3	IS Architecture Complexity → Revolutionary IS Change	0.358***	5.435	Supported
H4	Evolutionary IS Change → IS Architecture Outcomes	0.537***	7.759	Supported
H5	Revolutionary IS Change → IS Architecture Outcomes	0.001	0.016	Not supported

We find support for *H1*, i.e., there is a significant negative relation between IS architecture complexity and IS architecture outcomes (see Figure 2). However, this relation needs to be critically reflected in light of the entire structural model: Once we include mediation effects by considering total effects in the model (see Table 5), we no longer find a statistically significant relation. Thus, on the one hand the observed effect sizes (f^2) and determination coefficients (R^2) for H1 are similar to previous quantitative studies (Aleatrati Khosroshahi et al. 2016; Beese et al. 2016; Mocker 2009; Xia and Lee 2005). On the other hand, our results also indicate that this is a highly non-trivial and not necessarily clearly negative relation, when additionally considering indirect positive effects through the change constructs. This is in line with extant qualitative and theoretical studies that focus the integral specificities of IS complexity as a dynamic socio-technical phenomenon (Benbya and M. McKelvey 2006; Merali 2006; Mocker et al. 2014); also see (Amarilli et al. 2016) for a recent literature review.

Looking at the connection between IS architecture complexity and revolutionary as well as evolutionary IS change, we find support for both *H2* and *H3*: IS architecture complexity is positively related to evolutionary IS change (*H2*, $p < .05$) and IS architecture complexity is positively related to revolutionary IS change (*H3*, $p < .01$). In accordance with the principles of coevolving, self-renewing organizations, we thus confirm that complex IS architecture adapts and evolves through both evolutionary and revolutionary IS changes.

Regarding the effects of the change constructs in the model, we find support for *H4* (a positive relation between continuous change and IS architecture outcome, $p < 0.01$) but not for *H5* (a negative relation between revolutionary IS change and IS architecture outcome, $p > 0.1$). Consequently, while we do not find the expected contrasting negative (*H5*) relation for revolutionary IS change compared to evolutionary IS change, these results still show that revolutionary and evolutionary IS change are not only fundamentally different constructs in terms of discriminant validity (see Table 3), but also have fundamentally different effects (see Table 5).

Discussion and Conclusion

With this study, we want to better understand the relation between IS architecture complexity and expected IS architecture outcomes. Based on the theoretical lens of CAS, we derive five hypotheses that conceptualize the impact of IS architecture complexity on IS efficiency and IS flexibility as architectural outcomes. We test our model with a PLS approach to SEM, using survey data from 185 respondents. Our results clarify the intricate nature of the relation between IS architecture complexity and IS architecture outcomes by evaluating both direct effects and indirect effects through mediating revolutionary and evolutionary IS change constructs. By considering revolutionary and evolutionary IS change as mediation effects, our model

investigates the relation between IS architecture complexity and the expected IS architecture outcomes in more detail, finding no significant total effect (see Table 5). In the following we discuss these findings in the context of ongoing academic discussions.

On the one hand, our analysis of the direct, negative relation between IS architecture complexity and the expected IS architecture outcomes (H1) is in line with extant quantitative studies: relying on PLS-SEM (Beese et al. 2016) and regression analysis (Aleatrati Khosroshahi et al. 2016; Mocker 2009). On the other hand, an analysis of the total effects (i.e., by considering the mediation effects of IS change) in our structural model (see Table 5) shows that this relation is not statistically relevant. This finding corresponds to extant theoretically and qualitatively grounded discussions that posit complexity to be an inherent property of IS architecture, which is neither generally good nor generally bad (e.g., Boisot 2006; Vessey and Ward 2013). By acknowledging socio-technical complexity and corresponding dynamics as integral characteristics of IS architecture, our model captures how IS architecture co-evolves with environmental changes through evolutionary and revolutionary changes to achieve expected outcomes.

Concerning the hypothesized positive relations between IS architecture complexity and evolutionary IS change (H2) as well as revolutionary IS change (H3), we find support for both in our data (see Figure 1 and Table 6). However, the interpretation of the observed results requires some consideration, as our method does not give us an answer to the precise nature of the relations in H2 and H3. We thus briefly elaborate on how IS architecture complexity may, for example, enable (e.g., Vessey and Ward 2013) or compound IS change (Lyytinen and Newman 2008). From a CAS perspective, a certain level of complexity is considered a requisite property to enable the dynamic, emergent behavior of IS architecture (Benbya and M. McKelvey 2006; Holland 1995; Vessey and Ward 2013). Complexity causes the constituent elements of IS architecture to “interact in unpredictable and non-linear ways” (Lyytinen and Newman 2008, p. 606), which may lead to misalignments in the underlying deep structure of the IS and subsequently cause revolutionary changes (Lyytinen and Newman 2008). While our analysis does not allow for such rich descriptions, we can still conclude that there is a statistically relevant positive relation that associates IS architecture complexity with both revolutionary and evolutionary modes of IS change.

Further, we find that increasing levels of evolutionary and revolutionary change affect the expected outcomes of IS architecture very differently. In line with Rolland et al. (2015), we observe that evolutionary IS change is positively associated with IS efficiency and IS flexibility (H4). On the other hand, we find no direct statistical relation between revolutionary IS change and IS architecture outcomes (H5). This does, however, not imply that there are no effects. For example, revolutionary changes may have both, immediate negative effects due to disruptions and discontinuations (Lyytinen and Newman 2008) as well as long-term positive effects due to resolved misalignments (Lyytinen and Newman 2008; Vessey and Ward 2013).

Considering the three principles of coevolving, self-renewing organizations, our research shows that key concepts of CAS are observable in IS architecture. We find that IS architectures manage to adapt to changes in the environment (i.e., IS architecture complexity, principle I) through evolutionary and revolutionary IS change (i.e., principle III). The positive relation between evolutionary IS change and IS architecture outcomes is supporting the positive impact of constant interactions among IS architecture stakeholders (i.e., the concept of autonomous, interconnected agents, principle II)

In sum, our results (Figure 2 and Table 5) allow us to answer our research question—*How does IS architecture complexity affect IS flexibility and IS efficiency?*—by simultaneously explaining two seemingly contradictory findings: there is both, (i) a significant direct negative relation between IS architecture complexity and IS architecture outcomes without mediation, as well as (ii) no significant relation between IS architecture complexity and IS architecture outcomes when considering additional mediation effects through IS change. This is due to the existence of two different statistically significant paths in the model. There is a negative impact of IS architecture complexity on IS efficiency and IS flexibility. However, we also find that IS architecture complexity is positively related with evolutionary IS change, and that evolutionary IS change has a positive impact on IS architecture outcomes. In sum, negative direct effects and positive indirect effects through evolutionary IS change are balanced in the sense that they do not lead to a statistically significant total effect on IS architecture outcomes.

Limitations

Choosing survey-based PLS-SEM as our research approach enables us to derive interesting results, it also limits the extent to which we can understand the observed phenomena in more detail. To avoid misinterpretation of our results, we therefore point out two important limitations of this research.

First, one needs to consider the implications of using PLS-SEM with SmartPLS as an approach to study complex phenomena that may fundamentally be non-linear. We essentially performed a simultaneous series of linear regressions to minimize the overall sum of square residuals in the model. While statistically relevant, the observed relation between IS architecture complexity and IS architecture outcomes may only be a rough approximation of a truly non-linear relation: Aleatrati et al. (2016) do indeed observe an exponential relation based on a much larger dataset from a single organization. We conducted tests for similar exponential models in R, but did not find a statistically relevant relation. This may either be due to our comparatively (for non-linear analyses) small dataset compared to Aleatrati et al. (2016), or due to using survey-based data. Relying on Likert-type scales implies, for example, that the investigated phenomena allow an ordinal, equidifferent comparison of data (Allen and Seaman 2007). Consequently, while we phrased our items to clearly capture a theory based description of IS architecture complexity and IS change, there may still be certain turning points in the perceptions of these phenomena, so that, for example, the difference between a perceived '3' and '4' is larger than between '2' and '3'.

Second, our data does not allow for longitudinal analyses. Many of the hypothesized positive or negative effects of IS complexity or IS change may only be present during either revolutionary or evolutionary phases (Lyytinen and Newman 2008). In addition to that, one should consider that the respondents may have been biased when being asked about recent change activities (regency effect) (Baddeley and Hitch 1993). Consequently, we cannot pick up on such effects; however, different approaches, such as case-studies or simulation-based research, may build upon this manuscript and provide further insights.

Third, our current data does not allow us to discuss the impact of contextual factors such as the initial level of IS architecture complexity or the complexity of the environment of a respective organization. Several studies describe a turning point between emerging levels of complexity and the edge of chaos, affecting the appropriate response strategy of a system (i.e., type of IS change) (Benbya and M. McKelvey 2006; Page 2009). An initial but not statistically relevant analysis indicates that simple (i.e., less complex) systems compared to complex systems benefit (i.e., improved IS efficiency and IS flexibility) more from continuous change while complex systems benefit more from revolutionary change.

Implications

Our research builds on and contributes to extant research on the effects of IS architecture complexity: the proposed structural model allows us to bridge quantitative studies (Aleatrati Khosroshahi et al. 2016; Beese et al. 2016; Mocker 2009) with more detailed qualitative and theoretical studies (Mocker et al. 2014; Vessey and Ward 2013). By including change as a central mediating construct, we obtain an overarching model that simultaneously accounts for the significant direct relation between IS architecture complexity and the expected IS architecture outcomes and for the nonsignificant mediated relation. This demonstrates the potential of the CAS perspective to analyze the dynamics of IS architecture.

Furthermore, this research intends to contribute to the field of complexity science by describing an instance of CAS, i.e., IS architecture. By analyzing and discussing the different modes of change, we address the difficulty to empirically reflect the abstract constructs of CAS theory in the IS domain (Vidgen and Wang 2009).

Future research may extend our results by analyzing the observed statistical relations through methods that cater to the dynamic and emergent behavior of CAS, i.e., support multi-level and longitudinal analysis (Haki et al. 2016). By sending a similar questionnaire to the respondents multiple times, one could start analyzing longitudinal effects such as the longtime effect of revolutionary change on IS architecture outcomes.

Similarly, our results hold an important lesson for practitioners: understanding both direct and indirect effects in the context of IS architecture is important. The main message of our research is, that partial considerations lead to potentially wrong conclusions. IS architecture is an enduring effort that comprises both, evolutionary and revolutionary IS change. While in periods of revolutionary IS change, efficiency

measures tend to decrease, such change may still be necessary to obtain a sustainable and eventually effective IS architecture in the long run (Lyytinen and Newman 2008).

Acknowledgements

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

References

- Aanestad, M., and Jensen, T. B. 2011. "Building Nation-Wide Information Infrastructures in Healthcare through Modular Implementation Strategies," *The Journal of Strategic Information Systems* (20:2), pp. 161-176.
- Aleatrati Khosroshahi, P., Beese, J., and Aier, S. 2016. "What Drives Application Portfolio Complexity? An Empirical Analysis of Application Portfolio Cost Drivers at a Global Automotive Company," *IEEE 18th Conference on Business Informatics (CBI)*, Paris, France, pp. 282-289.
- Allen, I. E., and Seaman, C. A. 2007. "Likert Scales and Data Analyses," *Quality Progress* (40:7), pp. 64-65.
- Amarilli, F., van Vliet, M., and van den Hooff, B. 2016. "Business It Alignment through the Lens of Complexity Science," in: *37th International Conference on Information Systems (ICIS)*. Dublin, Ireland.
- Anderson, P. 1999. "Perspective: Complexity Theory and Organization Science," *Organization Science* (10:3), pp. 216-232.
- Ashby, W. R. 1956. *An Introduction to Cybernetics*. London: Chapman & Hall.
- Axelrod, R. 1984. *The Evolution of Cooperation*, (1 ed.). New York: Basic Books.
- Baddeley, A. D., and Hitch, G. 1993. "The Recency Effect: Implicit Learning with Explicit Retrieval?," *Memory & Cognition* (21:2), pp. 146-155.
- Beese, J., Aier, S., and Winter, R. 2015. "On the Role of Complexity for Guiding Enterprise Transformations," in *Advances in Enterprise Engineering IX: 5th Enterprise Engineering Working Conference, Eeuc 2015, Prague, Czech Republic, June 15-19, 2015, Proceedings*, D. Aveiro, R. Pergl and M. Valenta (eds.). Cham: Springer International Publishing, pp. 113-127.
- Beese, J., Haki, M. K., Aier, S., and Aleatrati Khosroshahi, P. 2016. "Drivers and Effects of Information Systems Architecture Complexity: A Mixed-Methods Study," *24th European Conference on Information Systems (ECIS)*, Istanbul, Turkey.
- Beetz, R., and Kolbe, L. 2011. "Towards Managing It Complexity: An It Governance Framework to Measure Business-It Responsibility Sharing and Structural It Organization," in: *17th Americas Conference on Information Systems (AMCIS)*. Detroit, USA.
- Benbya, H., and McKelvey, B. 2006. "Using Coevolutionary and Complexity Theories to Improve Is Alignment: A Multi-Level Approach," *Journal of Information Technology (Palgrave Macmillan)* (21:4), pp. 284-298.
- Bernus, P., Goranson, T., Götze, J., Jensen-Waud, A., Kandjani, H., Molina, A., Noran, O., Rabelo, R. J., Romero, D., Saha, P., and Turner, P. 2016. "Enterprise Engineering and Management at the Crossroads," *Computers in Industry* (79), pp. 87-102.
- Boh, W. F., and Yellin, D. 2006. "Using Enterprise Architecture Standards in Managing Information Technology," *Journal of Management Information Systems* (23:3), pp. 163-207.
- Boisot, M. 2006. "Moving to the Edge of Chaos: Bureaucracy, It and the Challenge of Complexity," *Journal of Information Technology* (21:4), pp. 239-248.
- Cherns, A. 1987. "Principles of Sociotechnical Design Revisited," *Human Relations* (40:3), pp. 153-162.
- Cohen, M. D., and Axelrod, R. 1999. *Harnessing Complexity: Organizational Implications of a Scientific Frontier*. New York: Free Press.
- Cohen, W. M., and Levinthal, D. A. 1990. "Absorptive Capacity: A New Perspective on Learning and Innovation," *Administrative Science Quarterly* (35:1), pp. 128-152.
- Curşeu, P. L. 2006. "Emergent States in Virtual Teams: A Complex Adaptive Systems Perspective," *Journal of Information Technology* (21:4), pp. 249-261.
- Dern, G., and Jung, R. 2009. "It-Architektur-Governance Auf Basis Von Kennzahlen Zur Komplexitätsmessung," *Controlling* (21:12), pp. 669-672.
- Gefen, D., Karahanna, E., and Straub, D. W. 2003. "Trust and Tam in Online Shopping: An Integrated Model," *MIS Quarterly* (27:1), pp. 51-90.

- Gefen, D., Rigdon, E. E., and Straub, D. 2011. "An Update and Extension to Sem Guidelines for Administrative and Social Science Research," *MIS Quarterly* (35:2), pp. iii-A7.
- Gefen, D., and Straub, D. 2005. "A Practical Guide to Factorial Validity Using Pls-Graph - Tutorial and Annotated Example," *Communications of the AIS* (16:5), pp. 91-109.
- Gersick, C. J. G. 1991. "Revolutionary Change Theories: A Multilevel Exploration of the Punctuated Equilibrium Paradigm," *Academy of Management Review* (16:1), pp. 10-36.
- Götz, O., Liehr-Gobbers, K., and Krafft, M. 2010. "Evaluation of Structural Equation Models Using the Partial Least Squares (Pls) Approach," in *Handbook of Partial Least Squares: Concepts, Methods and Applications*, V.E. Vinzi, W.W. Chin, J. Henseler and H. Wang (eds.). Heidelberg: Springer, pp. 691-711.
- Greenwood, R., and Hinings, C. R. 1996. "Understanding Radical Organizational Change: Bringing Together the Old and the New Institutionalism," *Academy of Management Review* (21:4), pp. 1022-1054.
- Hair, J. F., Jr., Ringle, C. M., and Sarstedt, M. 2013. "Partial Least Squares Structural Equation Modeling: Rigorous Applications, Better Results and Higher Acceptance," *Long Range Planning: International Journal of Strategic Management* (46:1-2), pp. 1-12.
- Hair Jr., J. F., Hult, G. T. M., Ringle, C. M., and Sarstedt, M. 2014. *A Primer on Partial Least Squares Structural Equation Modeling (Pls-Sem)*. Los Angeles, CA: Sage.
- Haki, M. K., Aier, S., and Winter, R. 2016. "A Stakeholder Perspective to Study Enterprisewide IS Initiatives," *24th European Conference on Information Systems (ECIS)*, Istanbul, Turkey.
- Haki, M. K., and Legner, C. 2013. "The Dynamics of IS Adaptation in Multinational Corporations: A New Theoretical Lens," *2013 International Conference on Information Systems (ICIS 2013)*, Milano, Italy: Association for Information Systems.
- Hanseth, O., and Bygstad, B. 2012. "Ict Architecture and Project Risk in Inter-Organizational Settings," in: *20th European Conference on Information Systems (ECIS)*. Barcelona, Spain.
- He, Z.-L., and Wong, P.-K. 2004. "Exploration Vs. Exploitation: An Empirical Test of the Ambidexterity Hypothesis," *Organization Science* (15:4), pp. 481-494.
- Henseler, J., Ringle, C., and Sarstedt, M. 2015. "A New Criterion for Assessing Discriminant Validity in Variance-Based Structural Equation Modeling," *Journal of the Academy of Marketing Science* (43:1), pp. 115-135.
- Holland, J. H. 1995. *Hidden Order: How Adaptation Builds Complexity*. Addison Wesley Longman Publishing Co., Inc.
- Iso/Iec/Ieee. 2011. "Systems and Software Engineering – architecture Description (Iso/Iec/Ieee 42010:2011)."
- Kim, R. M., and Kaplan, S. M. 2006. "The Co-Evolutionary Dynamics of IS Engagement," *14th European Conference on Information Systems (ECIS)*, Göteborg, Sweden.
- Kutner, M., Nachtsheim, C., Neter, J., and Li, W. 2005. *Applied Linear Statistical Models*, (5th ed.). McGraw-Hill/Irwin.
- Lange, M., Mendling, J., and Recker, J. 2016. "An Empirical Analysis of the Factors and Measures of Enterprise Architecture Management Success," *European Journal of Information Systems* (25:5), pp. 411-431.
- Lankhorst, M., van Buuren, R., van Leeuwen, D., Jonkers, H., and ter Doest, H. 2004. "Enterprise Architecture Modelling - the Issue of Integration," *Advanced Engineering Informatics* (18:4), pp. 205-216.
- Levinthal, D. A., and March, J. G. 1993. "The Myopia of Learning," *Strategic Management Journal* (14), pp. 95-112.
- Link, G., and Germonprez, M. 2016. "Understanding Open Source Communities as Complex Adaptive Systems: A Case of the R Project Community," in: *22nd Americas Conference on Information Systems (AMCIS)*. San Diego, USA.
- Luse, A., and Mennecke, B. 2014. "It Can Matter: Co-Evolution Fostering IT Competitive Advantage," *Management Research Review* (37:6), pp. 574-588.
- Lyytinen, K., and Newman, M. 2008. "Explaining Information Systems Change: A Punctuated Socio-Technical Change Model," *European Journal of Information Systems* (17:6), pp. 589-613.
- March, J. G. 1991. "Exploration and Exploitation in Organizational Learning," *Organization Science* (2:1), pp. 71-87.

- Matook, S., Soltani, S., and Maruping, L. M. 2016. "Self-Organization in Agile Isd Teams and the Influence on Exploration and Exploitation," in: *37th International Conference on Information Systems (ICIS)*. Dublin, Ireland.
- McKelvey, B. 2003. "Micro Strategy and Macro Leadership: New Science Meets Distributed Intelligence," in *The Coevolution Advantage: Mobilizing the Self-Renewing Organization*, A.Y. Lewin and H. Volberda (eds.). New York: Palgrave Macmillan.
- Merali, Y. 2006. "Complexity and Information Systems: The Emergent Domain," *Journal of Information Technology* (21:4), pp. 216-228.
- Mocker, M. 2009. "What Is Complex About 273 Applications? Untangling Application Architecture Complexity in a Case of European Investment Banking," in: *42nd Hawaii International Conference on System Sciences (HICSS)*. Big Island, HI, USA.
- Mocker, M., Weill, P., and Woerner, S. L. 2014. "Revisiting Complexity in the Digital Age," *MIT Sloan Management Review* (55:4), pp. 73-81.
- Morel, B., and Ramanujam, R. 1999. "Through the Looking Glass of Complexity: The Dynamics of Organizations as Adaptive and Evolving Systems," *Organization Science* (10:3), pp. 278-293.
- Muffato, M., and Faldani, M. 2003. "Open Source as a Complex Adaptive System," *Emergence* (5:3), pp. 83-100.
- Nan, N. 2011. "Capturing Bottom-up Information Technology Use Processes: A Complex Adaptive Systems Model," *MIS Quarterly* (35:2), pp. 505-532.
- Orlikowski, W. J. 1996. "Improvising Organizational Transformation over Time: A Situated Change Perspective," *Information Systems Research* (7:1), pp. 63-92.
- Page, S. E. 2009. *Understanding Complexity - Course Guidebook*. Chantilly, Virginia: The Great Courses.
- Richardson, G. L., Jackson, B. M., and Dickson, G. W. 1990. "A Principle-Based Enterprise Architecture: Lessons from Texaco and Star Enterprise," *MIS Quarterly* (14:4), pp. 385-403.
- Rigdon, E. E., Ringle, C. M., and Sarstedt, M. 2010. "Structural Modeling of Heterogeneous Data with Partial Least Squares," *Review of Marketing Research* (7), pp. 255-296.
- Ringle, C. M., Sarstedt, M., and Straub, D. W. 2012. "A Critical Look at the Use of Pls-Sem in Mis Quarterly," *MIS Quarterly* (36:1), pp. iii-xiv.
- Ringle, C. M., Wende, S., and Becker, J.-M. 2015. "Smartpls 3." Bönningstedt: SmartPLS.
- Roeleven, S., and Broer, J. 2009. "Why Two Thirds of Enterprise Architecture Projects Fail," *ARIS Expert Paper*.
- Rolland, K. H., Ghinea, G., and Gronli, T.-M. 2015. "Ambidextrous Enterprise Architecting: Betting on the Future and Hacking Path-Dependencies," in: *23rd European Conference on Information Systems (ECIS)*. Münster, Germany.
- Ross, J. W. 2003. "Creating a Strategic It Architecture Competency: Learning in Stages," *MIS Quarterly Executive* (2:1), pp. 31-43.
- Sabherwal, R., Hirschheim, R., and Goles, T. 2001. "The Dynamics of Alignment: Insights from a Punctuated Equilibrium Model," *Organization Science* (12:2), pp. 179-197.
- Schmidt, C., and Buxmann, P. 2011. "Outcomes and Success Factors of Enterprise It Architecture Management: Empirical Insight from the International Financial Services Industry," *European Journal of Information Systems* (20:2), pp. 168-185.
- Schneider, A., Reschenhofer, T., Schütz, A., and Matthes, F. 2015. "Empirical Results for Application Landscape Complexity," in: *48th Hawaii International Conference on System Sciences (HICSS)*. Kauai, HI, USA.
- Schütz, A., Widjaja, T., and Gregory, R. W. 2013a. "Escape from Winchester Mansion – toward a Set of Design Principles to Master Complexity in It Architectures," *34th International Conference on Information Systems (ICIS)*, Milan, Italy, pp. 1–19.
- Schütz, A., Widjaja, T., and Kaiser, J. 2013b. "Complexity in Enterprise Architectures - Conceptualization and Introduction of a Measure from a System Theoretic Perspective," *21st European Conference on Information Systems (ECIS)*, Utrecht, Netherlands: Association for Information Systems.
- Simon, D., Fischbach, K., and Schoder, D. 2013. "An Exploration of Enterprise Architecture Research," *Communications of the Association for Information Systems* (32:1), pp. 1-72.
- Sowa, J. F., and Zachman, J. A. 1992. "Extending and Formalizing the Framework for Information Systems Architecture," *IBM Systems Journal* (31:3), pp. 590-616.
- Tamm, T., Seddon, P. B., Shanks, G., and Reynolds, P. 2011. "How Does Enterprise Architecture Add Value to Organisations?," *Communications of the Association for Information Systems* (28:1), pp. 141-168.

- Tanriverdi, H., Rai, A., and Venkatraman, N. 2010. "Reframing the Dominant Quests of Information Systems Strategy Research for Complex Adaptive Business Systems," *Information Systems Research* (21:4), pp. 822-834.
- Vessey, I., and Ward, K. 2013. "The Dynamics of Sustainable Is Alignment: The Case for Is Adaptivity," *Journal of the Association for Information Systems* (14:6), pp. 283-311.
- Vidgen, R., and Wang, X. 2009. "Coevolving Systems and the Organization of Agile Software Development," *Information Systems Research* (20:3), pp. 355-376.
- Volberda, H. W., and Lewin, A. Y. 2003. "Guest Editors' Introduction Co-Evolutionary Dynamics within and between Firms: From Evolution to Co-Evolution," *Journal of Management Studies* (40:8), pp. 2111-2136.
- Widjaja, T., Kaiser, J., Tepel, D., and Buxmann, P. 2012. "Heterogeneity in It Landscapes and Monopoly Power of Firms: A Model to Quantify Heterogeneity," in: *33rd International Conference on Information Systems (ICIS)*. Orlando, USA.
- Winter, R. 2016. "Establishing 'Architectural Thinking' in Organizations," in *The Practice of Enterprise Modeling : 9th Ifip Wg 8.1. Working Conference, Poem 2016, Skövde, Sweden, November 8-10, 2016, Proceedings*, J. Horkoff, M.A. Jeusfeld and A. Persson (eds.). Cham: Springer International Publishing, pp. 3-8.
- Xia, W., and Lee, G. 2005. "Complexity of Information Systems Development Projects: Conceptualization and Measurement Development," *Journal of Management Information Systems* (22:1), pp. 45-83.
- Zachman, J. A. 1987. "A Framework for Information Systems Architecture," *IBM Systems Journal* (26:3), pp. 276-292.