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The Dynamics of Sustainable IS Alignment: The Case for IS Adaptivity

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Abstract

Our research addresses one of the most vexing issues in IS, that of how IS alignment occurs. Even more vexing, and largely unaddressed, is the issue of sustainable IS alignment. We address sustainable IS alignment as a dynamic, multi-faceted, and non-deterministic process based on the complexity theory worldview. The complexity theory worldview conceives of organizations and IS as complex adaptive systems (CAS) that co-evolve over time. Sustainable IS alignment results when an organization's complex adaptive IS adapt to remain in alignment with the constantly-changing (that is, evolving) organization's goals. Our co-evolutionary theory of IS alignment links bottom-up, emergent processes that foster adaptivity with top-down, formal organizational processes essential to established organizations. We illustrate the theory by applying it to the co-evolution and therefore adaptation of enterprise architectures and IS development projects. Our research on the role of co-evolution in sustainable IS alignment contributes to IS research in general and to prior research on IS alignment in particular, and has implications for achieving sustainable IS alignment. We believe that portraying organizations and their IS as complex adaptive systems that co-evolve provides both research and practice with a way to move forward in their endeavors to realize the potential benefits from using IS to enable businesses.

***Keywords**: Complexity Theory Worldview, Sustainable IS Alignment, Complex Adaptive Systems, Co-Evolution, Self-Organization, Emergence.*

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An issue that has remained relatively unchallenged and unquestioned is how to align a relatively fixed ICT that is implemented in an organization with a business strategy and associated information requirements that are in constant need of adjustment, while keeping in line with the dynamic nature of the organization's business imperatives (Galliers, 2007, p. 2).

1. Introduction

IS alignment has played a prominent role in information systems (IS) and IS research since its inception. For example, IT executives have ranked it as one of the top ten IS issues since such rankings were initiated almost 30 years ago. The persistence of IS alignment as a key issue is evidenced in reviews of the rankings of numerous key issues studies, for example, that of Watson and colleagues (Watson, Kelly, Galliers, & Brancheau, 1997), and also in more recent rankings by Luftman. Luftman and Ben-Zvi (2011), for example, report that, in the last nine years, IT and business alignment has been the number one issue six times, the number two issue twice, and the number three issue once. Further, the practitioner community has referred to IS alignment as the "Holy Grail of IT" (Jahnke, 2003), which reflects their belief that alignment of business and IS will result in better organizational performance.

Organizational performance benefits will accrue consistently, however, only when IS alignment is sustainable. By sustainable IS alignment, we mean the enduring fit between an organization's goals and its IS over time. The ability to maintain IS alignment over time is becoming increasingly important given the current global business environment, which is characterized by rapid interactions across global networks and by increasing pace of change. However, despite its importance, sustainable IS alignment has received little attention in the IS literature, which the introductory quotation above illustrates.

This research presents an explanatory theory of sustainable IS alignment. The approach we take adopts the complexity theory worldview, which is exemplified by notions of complex adaptive systems (CAS), emergence, and co-evolution (Axelrod & Cohen, 2000; Holland, 1995). Complexity theory offers "a way of looking at the world. It provides a set of concepts, a set of questions, and a set of design issues. By itself, it is not a falsifiable theory" (Axelrod & Cohen, 2000, p. xvi).

Complexity theory views CAS, both natural and artificial, as adapting to, and therefore co-evolving with, their environments (Levinthal, 1994). CAS are adaptive in that their individual and collective behavior changes as their environment changes. Organizations and their IS are artificial CAS (Axelrod and Cohen 2000). Complexity theory has gained considerable currency as a dynamic, non-deterministic process that is appropriate for explaining numerous organizational phenomena (Anderson, 1999; Lewin & Volberda, 1999).

CAS are dynamic networks of interactions and relationships rather than aggregations of static entities. As such, the complexity theory worldview allows us to examine IS alignment as a dynamic process whereby an organization's IS evolve with changes in the organization's external and internal environments. The organization's IS respond to the organization's needs (i.e., they support the organization's goals) in a co-evolutionary process that results in sustainable IS alignment. The co-evolutionary process of IS alignment is therefore synonymous with sustaining alignment over time.

To date, the IS research community has paid little attention to the complexity of IS and the organizations they support. The studies of Ciborra (1991) on using tinkering and bricolage in examining competitive advantage, of Weick (1993a) on using improvization in organizational redesign, and of Orlikowski (1996) on using improvization in organizational transformation all describe bottom-up, adaptive processes. In retrospect, therefore, we can interpret these studies using complexity theory. The complexity theory worldview, therefore, provides us with a consistent theoretical perspective for viewing such phenomena.

In this research, we develop the explanatory co-evolutionary theory of sustainable IS alignment using notions of CAS and co-evolution. Our research question is: "How does sustainable IS alignment occur?". The co-evolutionary theory of sustainable IS alignment is based on the assumption that sustainable alignment results when an organization and its IS co-evolve, which, in turn, results when the organization's IS are developed in such a way as to facilitate their adaptation to the changing organizational goals. Because IS are organizationally based, our theory explains the role of adaptive IS in organizational settings. Our theory suggests that adaptivity in the system development process must be tempered by top-down processes essential to established business organizations; that is, our theory links top-down formal organizational processes with bottom-up emergent processes that foster IS adaptivity.

The concepts presented in our co-evolutionary theory of sustainable IS alignment apply to all activities related to the provision of an organization's IS. We illustrate these concepts by examining co-evolution in both enterprise architectures and in IS development projects. We focus on enterprise architectures because of the significant impact that an organization's enterprise architecture has on performance in a rapidly changing world, and on IS development projects because of the additional insights that we gain over and above our analysis of enterprise architectures.

The remainder of our paper proceeds as follows. In Section 2, we justify our choice of the CAS and co-evolutionary notions of the complexity theory worldview in describing how sustainable IS alignment occurs. In Section 3, we present our co-evolutionary theory of sustainable IS alignment. In Section 4, we illustrate the applicability and utility of the theory in informing notions of sustainable IS alignment by examining the domains of enterprise architectures and IS development projects. In Section 5, we present the contributions of our theory and its implications for both future research and practice. Finally, we present our conclusions.

2. Theoretical Background

This section sets the scene for using the complexity theory worldview to inform sustainable IS alignment. We first justify the selection of complexity theory as an appropriate worldview for our dynamic process approach to sustainable IS alignment. We then introduce some of the basic tenets of CAS and co-evolution. Finally, we analyze prior research on IS alignment that takes a co-evolutionary perspective.

2.1. Justifying the Complexity Theory Worldview

Because we view IS alignment as a process whereby an organization's IS evolve with the continual changes that occur in the organization's external and internal environments, a theory of sustainable IS alignment requires a theoretical foundation that accommodates incremental changes in phenomena over time. The theory we are seeking is therefore evolutionary in nature. Evolution "explains change as a recurrent, cumulative, and probabilistic progression of variation, selection, and retention of organizational entities" (Van de Ven & Poole, 1995, p. 518). An evolutionary process theory is therefore an appropriate foundation for our notions of sustainable IS alignment as a process that occurs when an organization and its IS co-evolve.

A number of evolutionary process theories may be considered as potential theoretical bases for examining co-evolution (Lewin & Volberda, 1999). Organizational ecology (Hannan & Freeman, 1977, 1989), for example, focuses on the population level of organizations; that is, the environment in which organizations exist. It views the process of competition as akin to natural selection (adaptation, evolution), and is concerned with the birth of new organizations and organizational change, growth, survival, and mortality (Lewin & Volberda 1999). Institutional theory (DiMaggio & Powell, 1983) focuses on why organizations in a population exhibit similar characteristics. The theory suggests that longevity and survival of an organization is achieved when the organization remains consistent with changing industry norms (Lewin & Volberda, 1999). Because neither of the above theories focuses on the internal characteristics of the organization, they are not appropriate for informing an analysis of the alignment of IS with the organization.

The focus of the complexity theory worldview on CAS and their co-evolution with their environments makes it particularly relevant to studies of organizations (and therefore their IS), which organizational behavior literature that take a complexity theory perspective evidence. As one example, complexity theory is frequently used to inform studies of business agility (see, for example, Dyer & Ericksen, 2009). We therefore use notions of CAS and co-evolution as the foundation for our research into sustainable IS alignment.

2.2. Introducing the Complexity Theory Worldview

To develop a common language, and therefore a common understanding, we provide a brief introduction to notions of complexity by addressing non-linear relationships, self-organization, emergence, co-evolution, and history dependence. Where appropriate, we expand on these notions as we develop our co-evolutionary theory of sustainable IS alignment.

2.2.1. Non-linear Relationships

In general, organizational research has long been premised on the notion of linear effects manifested in simple cause/effect relationships, a view that promises that phenomena may be predicted and controlled. This approach is called into question, however, when used to address complex phenomena, such as weather forecasting. Further, because the majority of relationships in the world are believed to be non-linear, there are significant implications for the way in which we view control (Lucas: n.d.). Non-linearity results when large changes in input lead to small changes in output, and vice versa (Guastello, 1995). For example, examination of the counterintuitive observations from a case study describing the 1977 Tenerife airport disaster (Weick, 1993b) showed that small problems may become major disasters (Rudolph & Repenning, 2002).

2.2.2. Self-organization

From a structural perspective, CAS exhibit self-organization. That is, CAS evolve, or emerge, over time into a coherent form or pattern without any explicit management or control (Benbya & McKelvey, 2006a; Cilliers, 1998; Dooley, 1997; Holland, 1995). Any reorganization results from the desire of the CAS to find the best fit with its environment. Along these lines, Davis, Eisenhardt, and Bingham (2009) examine the optimal degree of structure to support improvization in dynamic environments.

2.2.3. Emergence

From a process perspective, the agents in such a system interact in apparently random (unplanned and uncontrolled) ways via a multiplicity of relatively simple interactions that produce complex systems and patterns. The resultant process is known as emergence (Choi, Dooley, & Rungtusanatham, 2001; Dooley, 1997; Holland, 1995; Lewin & Volberda, 1999). Emergence is a necessary consequence of viewing phenomena from a CAS and co-evolutionary perspective. As an example of emergence from an IS perspective, Curşeu (2006) argues that, in virtual teams, team cognition, trust, cohesion, and conflict are interdependent states that emerge from interactions of team members.

2.2.4. Co-evolution

Each element or component in an environment influences and is in turn influenced by all other related elements (components) in that environment in a process known as co-evolution. When a system changes to ensure best fit, its environment also changes, and those changes in its environment are likely to result in further system changes, and so on, resulting in continual system changes (Kauffman, 1993). Adaptation by any system in an environment therefore alters both its own adaptation to that environment and the adaptation of all the other systems in the environment. From an IS perspective, Vidgen and Wang (2006) examine the co-evolution of a firm's business processes and its information technology, while Nissen and Jin (2007) examine the co-design of organizations and IS.

2.2.5. Path Dependence

CAS reflect the history of the irreversible and unexpected events they have undergone (Axelrod & Cohen, 2000; Dooley, 1997); that is, they are history dependent. A CAS is shaped by the changing conditions along its evolutionary path and the approaches taken to address them. In essence, then, a CAS is any system featuring a large number of interacting components that exhibits self-organization and emergence under a certain level of tension, and whose aggregate activity is non-linear. Order in a CAS is therefore emergent rather than predetermined: the future of a CAS cannot be predicted, and its history is irreversible (Dooley, 1997).

2.3. Prior Research Using the Complexity Theory Worldview in IS Alignment

More recently, a number of IS journals have published special issues on the use of complexity theory in IS; for example, the *Journal of Information Technology* on “Using complexity science to effect a paradigm shift in information systems for the 21st century” (Merali & McKelvey, 2006), *Information Technology and People* on “Complexity in IS research” (Jacucci, Hanseth, & Lyytinen, 2006), and *Information Systems Research* on “Flexible and distributed information systems development” (Ågerfalk, Fitzgerald, & Slaughter, 2009).

Nonetheless, in these three special issues, and in the broader literature, we identified just two extant studies that address IS alignment as a dynamic process. That dynamic process represents the co-evolution of IS with the organization. The two extant studies and our own study may be viewed on a continuum defined by the extent to which the research examines organizational and/or managerial issues in the co-evolutionary process. First, Allen and Varga’s (2006) study assumes that co-evolutionary IS alignment takes place at the level of the individual agents, essentially without reference to organizational issues. The authors examined “(t)he co-evolution of information systems (IS) and the processes that underpin the construction and development of IT systems” (p. 229). They assume that each agent has an idiosyncratic view of the organization, their own view of what they know and how they know it, and their own axiology (i.e., their own values and interests). They suggest, therefore, that each individual has their own IS based on their own epistemology and axiology. They then argue that, because the organization is made up of the interactions of all of the agents, an agent-based axiological framework is essential to understand the evolution of organizations.

Such a co-evolutionary process may be compared to that of an ant colony in which individual ants understand their roles and the activities in which they are permitted to engage. Note, however, that the dynamic process may evolve little over time. This study does raise the question, therefore, of how individuals work toward organizational goals—goals that change over time at a far greater rate than those of ant colonies—without management intervention.

Second, Benbya and McKelvey’s (2006a, p. 284) study addresses organizational issues—specifically, organizational structure. These authors examine the emergent nature of IS alignment by focusing on “coevolution-based self-organized emergent behavior and structure”. They view IS alignment as taking place via a series of adjustments at individual, operational, and strategic levels of an organization. In addition to viewing IS alignment as co-evolution in terms of these three organizational levels, their research examines a number of adaptive principles and power laws that may be used to encourage emergence and therefore co-evolution.

Our study posits an explicit role for management by addressing the dynamic, co-evolutionary process of IS alignment in the context of broader management issues. Specifically, the theory we develop recognizes that bottom-up adaptive IS processes take place in the context of the top-down processes essential to established business organizations.

3. The Co-Evolutionary Theory of Sustainable IS Alignment

We now present the co-evolutionary theory of IS alignment, which addresses our research question: “How does sustainable IS alignment occur?”. We present, in turn, the foundations of our theory, the theory itself, and the boundaries of the theory.

3.1. Theoretical Foundations

We first define alignment and then present the foundational premises of our theory.

3.1.1. Definition of Alignment

As we have seen, organizations and IS are artificial CAS. Simon's (1996) theory of artifacts informs us that artificial systems are characterized by their internal structure, their purpose (or goal), which effectively forms the interface to their environment, and the environment itself. An artifact therefore serves its intended purpose when it responds appropriately to the conditions in its environment. Hence, an artifact is aligned with its environment when the goals it fulfils are consistent with the goals of the environment in which it exists (see also Axelrod & Cohen, 2000).

From the perspective of IS alignment, then, an organization and its IS are aligned when the organization's IS support the organization's goals. Hence, an organization's IS need to adapt over time to remain in alignment with the constantly-changing (evolving) organizational goals.

3.1.2. Foundational Premises

Three fundamental premises underlie our theoretical approach to sustainable IS alignment. The first premise is that, if an organization is to succeed in a fast-paced world, it must be capable of appropriate adaptation. The second premise is that the organization's IS respond as needed to changes in the organization's goals. The third premise is that organizations engage, at some level, in formal, hierarchical control.

3.1.2.1 Organization Responds to Changes in its Environment

The complexity theory worldview applies to a domain between deterministic order and randomness (Cilliers, 1998). Deterministic order, or deterministic complexity, is displayed by chaotic systems. Chaotic behavior is the result of a relatively small number of non-linear interactions. When the initial conditions and the context of the action are known, chaos theory can predict the course of action.

Complex systems, on the other hand, are neither deterministic nor random. They are, instead, regarded as being at the edge of chaos, which means that they are far from equilibrium or constantly changing. Complex systems at the edge of chaos (Lewin, 1994), or, more intuitively, the region of emergent complexity (McKelvey, 2003), may be regarded as being in a quasi-equilibrium state. Therefore, CAS may maintain order while still being able to react to changes in their environment (Choi et al., 2001). In short, to allow for the possibility of sustainable IS alignment, an organization must be in the region of emergent complexity.

3.1.2.2. Organization's IS Adapt Spontaneously to Changes in Organization's Goals

As we have seen, a CAS changes its structure and/or behavior in response to interactions with other CAS. Adaption by one CAS alters the fitness of other CAS in its environment, which leads to further adaptations in a process of repeated mutual adaptation or co-evolution (Kauffman, 1993; Simon, 1996). Co-evolution that supports sustainable IS alignment results when an organization's complex adaptive IS adapt or evolve to support the changes that are occurring in the complex adaptive organization. More specifically, a change in the organization's environment may motivate a change in the organization's goals, which, in turn, may motivate changes in the organization and therefore in the organization's IS.

In short, sustainable IS alignment occurs when an organization's IS change so that they support the organization's goals over time. Hence, IS adaptivity enables sustainable IS alignment.

3.1.2.3. Organizations Engage, to Varying Extents, in Formal Hierarchical Control

An established organization does not consist of interdependent agents constrained only by the environment and the responses of their peers. If an agent were to change the IS platform in a complex adaptive organization to get the best fit for their specific environment, the environment for each of the agents throughout the organization would also need to change. The number of resulting adaptations that would propagate throughout the organization is difficult to imagine.

Even if we acknowledge that organizations consist not of agents but of groups of interdependent agents that share similar objectives (e.g., in structures such as departments), the same argument holds; that is, a department is not free to "do its own thing". For example, IT personnel cannot simply change the computing platform without considering the ramifications of those changes for activities in the marketing department, the production department, the accounting department, and so on. The management literature is rife with examples of organizations in which departments have sought to optimize their own performance at the expense of the performance of other inter-related departments.

Below, we present two quotations that support this notion. Uhl-Bien, Marion, and McKelvey (2007, p. 305) state:

> *In formal organizations, one cannot disentangle bureaucracy from CAS. Earlier we stated that CAS are the basic unit of analysis in a complex system. However, as all organizations are bureaucracies (there are no such things as "post-bureaucratic" organizations, Hales 2002). CAS necessarily interact with formal bureaucratic structures in organizations.*

Stamps and Lipnack make similar unequivocal statements (2009a, p. 1):

> *While people like to think that hierarchy is irrelevant, it is nevertheless unavoidable. If you doubt this, try to collect your paycheck without the hierarchy …. most people on earth are paid by formal structures.*

In short, our research is based on the premise that an organization cannot be successful if allowed to proceed unfettered and unmonitored. That is, certain top-down initiatives are essential to facilitate the notion of adaptive IS in an organizational context. The theory we develop therefore explains how sustainable IS alignment occurs in an established organization that engages in both top-down control and bottom-up adaptation.

3.2. Theory

We first set the scene for our theory of sustainable IS alignment. We then present the concepts and the associations in the theory.

3.2.1. Introduction to the Theory

We now introduce the characteristics of the theory, followed by our conceptual model.

3.2.1.1. Characteristics of the Theory

The theory we describe is a Type II theory, a theory for explaining (Gregor, 2006). Such a theory "explains primarily *how* and *why* some phenomena occur. These theories are formulated in such a way, however, that making testable predictions is not of primary concern" (emphasis in original) (p. 624).

We seek to explain how an organization's IS may remain aligned with the organization's needs in an environment that changes over time; that is, how sustainable IS alignment occurs. Describing this phenomenon theoretically lays the foundation for a normative theory that prescribes how sustainable IS alignment may be brought about.

The theory we present is a process theory. We describe the dynamic process of sustaining alignment over time in an environment in which the organization changes in response to changes in its environment and in which the organization's IS must adapt to support the changed organizational goals. As we have seen, our process theory is underpinned by an evolutionary motor (Van de Ven & Poole, 1995). The complexity theory worldview we adopt describes organizations and their IS as CAS; that is, as systems that continually adapt to changes occasioned by the interactions among CAS.

We draw on Weber's (2012) model for theory development to the extent possible. Given that we are proposing a non-deterministic process theory in a complexity theory worldview, we refer, however, to concepts rather than to constructs (see Axelrod & Cohen, 2000, p. xvi, cited in Section 1 of this paper). Further, because we cannot present strict associations, as would be the case in a positivist theory, we present insights into associations in CAS.

Further, we do not undertake direct theory evaluation. Rather, we use logic to support our arguments. As Whetten (1989, p. 491) states: “During the theory-development process, logic replaces data as the basis for evaluation”. Instead, we illustrate the applicability of our theory in two domains:enterprise architectures and IS development projects.

3.2.1.2. Conceptual Model

Our theory addresses how sustainable IS alignment occurs by focusing on the development of adaptive IS to fulfil organizational goals in the broader organizational context. In developing our conceptual model, we make an analogy to complexity leadership theory of Uhl-Bien et al. (2007). These authors view leadership in a fast-paced organization as a process involving traditional top-down, hierarchical (administrative) leadership, evolutionary (adaptive) leadership, and enabling leadership. Enabling leadership is required to support the relationship between formal, administrative leadership and informal, adaptive leadership. By analogy to leadership research, we address the three types of management needed to support adaptive IS processes as administrative, adaptive, and enabling IS management, respectively.

Figure 1 presents a model of our explanatory, process-based theory of sustainable IS alignment. The left of the figure shows the adaptive IS management responsible for the development and maintenance of IS that co-evolve with the changing organization. The right of the figure shows that adaptive IS management takes place in the context of the traditional IS function, known as administrative IS management, while a further structure, enabling IS management, mediates the relationship between the adaptive and traditional forms of IS management.

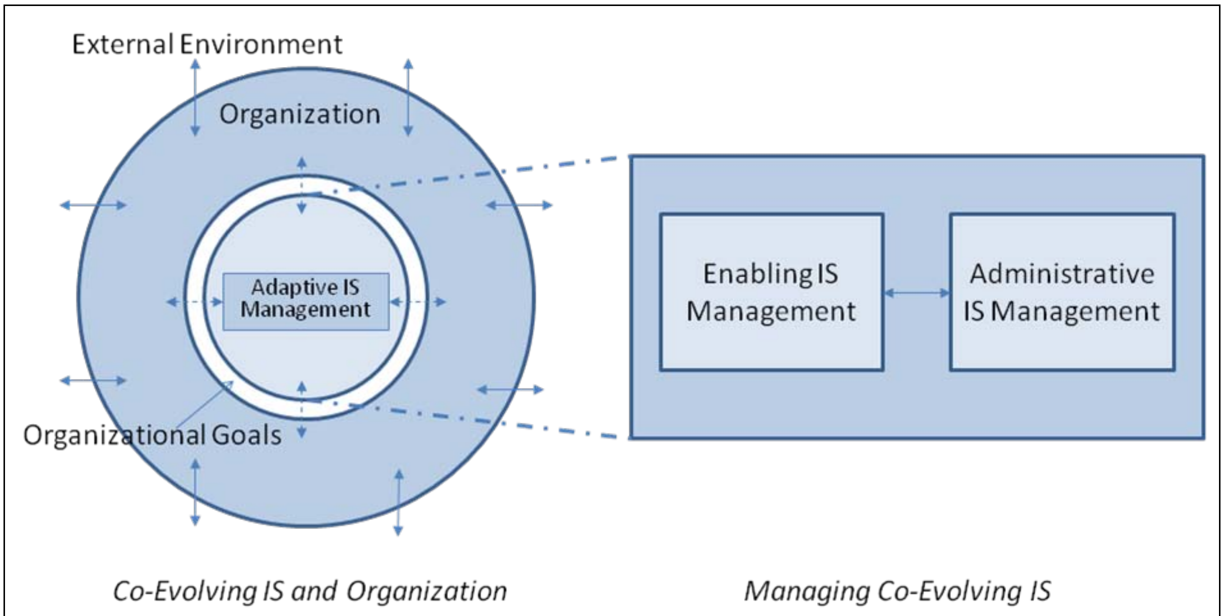

Figure 1. Conceptual Model of Sustainable IS Alignment

3.2.2. Concepts in the Theory

We now present the theoretical principles related to adaptive, administrative, and enabling IS management, in turn. Table 1 presents indicators of these principles.

3.2.2.1. Adaptive IS Management Principles

Adaptive IS management is an informal, emergent dynamic that arises among interactive agents in a CAS in response to tensions in the environment (Uhl-Bien et al., 2007). Such tensions may arise via goals that are generated either externally or are self-organized by external conditions such as marketplace opportunities, challenges, or threats, or by internal factors such as interactions among agents and recognition of opportunities (McKelvey, 2004). In adaptive IS management, many agents from across organizational boundaries may come together to learn, innovate, and collaborate to address complex challenges, and resolve task-related conflict. It is therefore a type of coordinated, distributed leadership (Gronn, 2004). Thus, adaptive IS management focuses on emergence and self-organization, innovation, and learning.

Table 1. Indicators of Concepts in the Theoretical Model

Principles	Indicators	
Adaptive IS management principles		
Principle 1: Match co-evolutionary change rates	Rate of change in organization's IS >= rate of change in its environment Requisite complexity in organization's IS >= requisite complexity in its envmt # responses available to organization's IS >= # challenges in environment	
Principle 2: Optimize self-organization	Spontaneous problem solving Emergent structures/roles; that is, there are no formal: • Group members, group leader • Plans, or • Control.	
Principle 3: Synchronize exploitation and exploration	**Exploitation:** • Uses existing resources • Focuses on the short-term • Offers stability	**Exploration:** • Opens up new avenues • Focuses on the longer-term • Offers flexibility / innovation
Administrative IS management principles		
Administrative IS management	Role of executive IS management Engages in top-down planning, allocation of resources, etc., control, and monitoring Focuses on order, stability, and predictability	
Enabling IS management principles		
Enabling IS management	Manages links between top-down (administrative) and bottom-up (adaptive) management processes • Establishes conditions for adaptive IS management • Mediates relationship between administrative and adaptive IS mangement processes	

The complexity science literature has addressed in depth the principles that underlie any theory of co-evolution in an organizational context. We use the widely cited work of Volberda and Lewin (2003), which focuses on "three basic higher-order principles", as the basis for examining adaptive IS management. Those principles are: 1) matching internal rates of change to the relevant external rates of change, 2) "optimizing" self-organization, and 3) "synchronizing" exploitation and exploration. We need to caution, however, that these three principles are not the only principles addressed in the literature, nor are they equally applicable in all situations, as we show in Sections 4 and 5. We address these three principles in turn.

3.2.2.1.1. Principle 1: Match Co-evolutionary Change Rates

This principle states that effective co-evolution occurs when the internal organizational rates of change either match or exceed the rates of change in their environment (McKelvey, 2003; Mitleton-Kelly, 2003; Volberda & Lewin, 2003). Therefore, over time, the complexity of systems increases in response to the increasing complexity in the environment. In more recent times, such changes are largely due to increased connectivity and globalization.

Based on the notion of requisite variety (Ashby, 1968), which is perhaps more aptly named requisite complexity (McKelvey, 2003), an organization may remain viable by ensuring that the variety of responses (internal complexity) is equal to, or exceeds, the variety of the environmental perturbations (external complexity). The larger the number of responses available to a system the larger the set of perturbations, disturbances, and/or uncertainties that it may accommodate, and therefore the larger the number of potential external situations in which the system may exist (Lycett & Paul, 1999). In effect, then, external complexity may be managed or even eliminated by matching it with a similar degree of internal complexity.

To achieve matching rates of change or better, CAS establish routines to measure, monitor, and track rates of change in all aspects of their environment and adjust their internal rates of change to match or exceed them (Volberda & Lewin, 2003). CAS may also accommodate more rapidly changing environments by increasing the speed of learning action loops (McKelvey, 2004). Adaptation, however, may proceed only as fast as the rate at that usable knowledge, learning, innovation, networking, and agent skills, and so on become available.

From an IS perspective, when an organization adopts a new technology, it must either hire new personnel or retrain existing personnel to increase the internal "variety" of technology knowledge available to match the "variety" of knowledge in the external environment. That might mean, for example, increasing the number of people in a specific function, increasing the variety of positions, and/or encouraging diverse ideas (Stamps & Lipnack, 2009b). An organization that has IT personnel with expertise in network technologies, for example, would be well placed to support the recent phenomenon of globalization.

3.2.2.1.2. Principle 2: Optimize Self-Organization

This principle states that a set of interconnected autonomous agents in a CAS organize themselves in such a way that they may best address the complexity in their environment (Volberda & Lewin, 2003). From an organizational viewpoint, self-organization results when a group of people come together spontaneously to achieve a goal or to solve a problem (Mitleton-Kelly, 2003). There is no formal plan and no control over what to do, how to do it, or when to do it; that is, the solution emerges from the interactions of the members. In such instances, self-organization replaces the command and control philosophy of the traditional organization (Volberda & Lewin, 2003).

Self-organization is particularly important when the task is complex and therefore not well understood. Because it is difficult to plan and manage top-down when the situation is not well defined, the preferred approach is to allow those closest to the issues the freedom to address them as they arise. It is important to note, however, that self-organization:

> *Does not mean that individuals or units can pull in all directions at will or break all rules. It does not mean that managers are not necessary or that they have diminished roles. It means that no central controller is necessary* (Volberda & Lewin, 2003, p. 2127).

Such a situation requires process rather than outcome controls (Volberda & Lewin, 2003).

Self-organization is consistent with empowerment and therefore the delegation of decision making to lower organizational levels. From an IS perspective, this principle is manifested when a project team working on a complex system devises ways to acquire the types of expertise, and the communications, and therefore the interactions, necessary for effective outcomes without intervention from the management hierarchy.

3.2.2.1.3. Principle 3: Synchronize Exploitation and Exploration

Volberda and Lewin's (2003) third principle focuses on the need to balance exploitation; that is, improving an organization's fundamental products and processes, at the same time as exploring new initiatives. Exploitation therefore describes activities that use or extend the organization's existing resources. Examples include incremental improvements in production and business processes, extension of an established product line, and a focus on efficiency. Exploration, on the other hand, describes activities that result in moving to a new order; for example, activities that explore new avenues for improving the effectiveness of the organization. Exploration focuses on innovation, learning, and the creation of new knowledge.

According to Levinthal and March (1993, p. 105), “the long-term survival of an organization depends on its ability to engage in enough exploitation to ensure the organization’s current viability and enough exploration to ensure its future viability” (see, also, March, 1991; Volberda & Lewin, 2003).

When an organization engages in too much exploitation, it focuses on short-term outcomes rather than longer-term viability, and suffers from rigidities in core competences and established resources (Volberda, 1996). On the other hand, when an organization engages in too much exploration, it suffers from unclear responsibilities, authority conflicts, inadequate controls, and lack of direction (Volberda & Lewin, 2003). Such an organization does not have a sense of identity and has difficulty in performing effectively over time (Weick, 1979).

From a conceptual perspective, the duality of exploitation and exploration is rooted in Dumont’s entangled hierarchy theory (see McKelvey, 2004) and features as coordination rhythm, dynamic rhythm, circular organizing, and/or entanglement. Causal dualities alternating on an irregular basis result in greater adaptation than a static or balanced state. Numerous management researchers have identified the phenomenon in terms of a number of other dualities that may be closely related to exploitation and exploration: formal versus informal organization, differentiation versus integration, top-down control versus bottom-up autonomy, and stability versus change. Stamps and Lipnack state (2009b, p. 5):

> *Organizations need order and stability, flexibility and creativity.... The structure must provide sufficient constraints to maintain integrity and enough freedom to innovate and adapt. Sufficient sameness and commonality have to mix with requisite variety and difference. Otherwise, the organization is either completely moribund or a total madhouse.*

The notion that a balance between exploitation and exploration is essential to organizational adaptation is supported extensively in both the management and IS literatures.

From an IS perspective, that organizations succeed by balancing stability (i.e., exploitation) and flexibility (that is, exploration) is supported in the work of Custodio, Thorogood, and Yetton (2007) on organization-wide IS. In a case study of the California Energy Commission, the authors propose that organizations must transition through chaotic (low stability, low flexibility) and rigid (high stability, low flexibility) stages before they may become agile (high stability, high flexibility) as they institute organizational roles and structures designed to provide the necessary IS functions to support the organization in its competitive environment.

3.2.2.2. Administrative IS Management Principles

Administrative IS management represents management in the formal hierarchy that is responsible for planning and coordinating formally-sanctioned IS activities. It therefore refers to the traditional activities of executive staff, which involve developing a vision for the organization’s IS, managing the organization’s IS strategy, planning and allocating resources, and dealing with crises and conflicts both within IS and between IS and other parts of the organization. Hence, administrative IS management focuses on order, stability, and predictability. For example, decisions on project selection and funding of IS/IT initiatives would be subject to administrative IS management. Administrative IS management is therefore responsible for examining the available alternatives (variation), making the choice about which ones to implement (selection), and then proceeding with establishing them in the organization (retention).

3.2.2.3. Enabling IS Management Principles

Enabling IS management has the responsibility for managing the coordination rhythms, or oscillations, between top-down hierarchical dynamics and emergent CAS; that is, between exploitation and exploration. Enabling IS management is responsible for: 1) establishing the conditions in which adaptive IS management can succeed, and 2) managing the relationship, or entanglement, between bureaucratic (administrative) and emergent (adaptive) IS management (cf. Uhl-Bien et al., 2007).

Because IS problem solving takes place in dual business and IS domains (i.e., application and technical domains) (Shaft & Vessey, 2006), enabling IS management in the IS arena differs somewhat from enabling management in the majority of domains. The IS domain is responsible for the application of concepts, tools, and techniques of the IS domain to solve problems in the application or business domain. When the business domain to be addressed is complex, there is a great deal of uncertainty about what is required of a new IS (see, for example, Brooks, 2010). Heavy involvement of both business and IS personnel at least in the initial stages is extremely effective in helping to determine the information requirements of a new system. The information requirements co-evolve as a result of the interactions, the consequent knowledge sharing, and the learning that take place between the two parties involved in the bottom-up, adaptive process. For a more detailed discussion of this process, see Rosemann, Vessey, & Weber (2004).

Enabling IS management therefore occurs primarily as a natural result of the interaction of both business and IS agents in the complex systems development process. On certain occasions, guidance or direction may be sought from senior executives not involved in the development process (e.g., via steering committees).

3.2.3. Associations in the Theory

A CAS is 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 (Holland, 1995; Uhl-Bien et al., 2007). These changeable, heterogeneous, interactive, and interdependent structures form multiple, overlapping hierarchies in which agents may quickly explore and develop solutions to address environmental pressures or tensions (Uhl-Bien et al., 2007). Directionalities may be "bottom-up, top-down, horizontal, diagonal, intermittent, and Aristotelian" (Benbya & McKelvey, 2006b, p. 21; see also Volberda & Lewin, 2003). Complex systems therefore manifest what is known as "causal intricacy." Causal intricacy is at the root of Simon's (1955) well-known notion of satisficing.

In complex situations, it is not possible, therefore, to identify cause and effect, to trace a path from cause to effect, or to describe definitively activities in such systems. Hence, it is not possible to take a traditional view of associations in a theory developed in the complexity theory worldview. In this view, associations are probability based rather than causal in nature (Axelrod & Cohen, 2000; Gell-Mann, 1997). As Axelrod and Cohen state (2000, p. 19), "complexity research does not make detailed predictions". Rather, by changing to ensure best fit with its environment, a CAS fosters increases in its value over time.

3.3. Boundaries of the Theory

We anticipate that our theory does not hold in all of the circumstances in which an organization seeks to sustain IS alignment. In particular, it will not hold when the three foundational premises that underlie our theory do not hold.

3.3.1. Organization is Not Sufficiently Adaptive

We have seen that a CAS that is adaptive is at the edge of chaos, or the region of emergent complexity. A CAS undergoes co-evolution when it is poised in a region defined by two critical values. An organization positioned below the lower critical limit cannot respond effectively to the adaptive tensions in its environment, which results in maintenance of the status quo. On the other hand, an organization positioned above the upper limit may respond by making inappropriate changes (e.g., too many changes), which results in a dysfunctional organization. In this case, the organization does not have sufficient stability to react appropriately to those changes. Innovation will therefore be successful when the organization is not too entrenched in established business, yet is sufficiently stable so that it may serve as a platform for change (Cilliers, 1998; Holland, 1995; McKelvey, 2003).

3.3.2. Organization's IS Cannot Adapt Spontaneously

To date, we have assumed that adaptation of the IS to the organization's changed goals occurs spontaneously; that is, each time the organization's goals change, the goals of the organization's IS change, and so, too, do the artifacts themselves. We now examine the adaptation process in greater depth. We then identify circumstances in which the organization's IS may not adapt effectively.

With regard to the adaptation process, first, when appropriately structured, an IS may remain adapted to its environment. Hence, it may, in limits, maintain an invariant relationship to its environment without altering its internal structure.

Second, the internal structure of a system becomes an issue only when the system is no longer able to fulfil its intended purpose in the environment in which it exists. Simon (1996, p. 11) states that, "in a taxing environment, we would learn something about its internal structure – specifically about those aspects of the internal structure that were chiefly instrumental in limiting performance". Furthermore, only a few of the characteristics of the environment drive the artifact to fulfil its intended purpose (Simon, 1996, p.11): "In very many cases, whether a particular artifact achieves a particular goal or adaptation depends only on a few characteristics of the outer environment and not at all on the details of the environment".

Sustainable IS alignment is therefore achieved when the organization's IS either absorb or respond to changes in the organization's goals. The key lies in organizing and structuring an organization's IS in such a way that they are insulated (or buffered) from their environment, and, in particular, the few elements of the environment that impact it in a major way (Simon, 1996).

With regard to the circumstances in which the organization's IS may not adapt spontaneously, we need to take a pragmatic view of the process of system change. First, intervention of the IS function is needed to make the required changes to realign the IS with the organization's goals. That is, IS personnel must modify the organization's IS in order to drive the co-evolutionary IS alignment process. Such changes to the organization's IS rely for their effectiveness and efficiency on the availability and skill levels of those personnel and on the approaches they use. The quality and experience of the organization's IS personnel therefore play an important role in the ability to make changes to adapt the organization's IS to organizational goals.

Second, the required changes are unlikely to take place one at a time. Typically, a number of changes will be batched so that they may be addressed as a whole, which results in less interference with everyday operations. Batching of changes means, however, that there is a time delay in conducting certain changes, thereby delaying the co-evolutionary IS alignment process.

Third, it is possible that an organization may choose to carry out just those changes to an organization's IS that are expected to result in improved organizational outcomes. While such a decision may not influence performance at that time, it may have consequences for later adaptation.

We see, therefore, that while 100 percent IS alignment will not be possible all of the time, the smaller the required changes to be made to the organization's IS, the quicker they will be implemented, and the more effective will be the IS alignment. And, indeed, the role of adaptive IS management in the development of organizational IS is to reduce the time taken compared with traditional IS development. Pragmatically, then, an organization's IS alignment is sustainable when the IS changes that respond to the organization's changed goals are relatively small and are therefore instituted as quickly as possible.

3.3.3. Organizations that do not Engage in Formal Hierarchical Control

In our original premise, we establish that typical organizations engage in formal hierarchical control. Over the past two decades, there has been considerable discussion in the literature regarding other types of organizations, such as networked organizations and virtual corporations. A networked organization is defined as follows: "independent people and groups act as independent nodes, links across boundaries, to work together for a common purpose; it has multiple leaders, lots of voluntary links and interacting levels" (Lipnack & Stamps, 1994).

This literature relates, therefore, to teams that come together to solve a specific problem rather than applying to fully-fledged organizations. Our theory does not apply to team-focused structures.

A virtual corporation or virtual enterprise:

> *refers to a new organizational form characterized by a temporary or permanent collection of geographically dispersed individuals, groups or organization departments not belonging to the same organization—or entire organizations, that are dependent on electronic communication for carrying out their production process* (Travica, 1998).

In short, while IS/IT plays a large role in networked organizations and virtual corporations, our view of sustainable IS alignment as involving both bottom-up adaptive and top-down administrative management does not apply to such entities because there is no role for administrative IS management.

4. Illustrating the Sustainable IS Alignment Process

Based on our co-evolutionary theory of sustainable IS alignment, an organization's IS support co-evolution when they are adaptive; that is, when they change to respond to changes in their environment. While the concepts presented in our theory apply to all IS development activities, for purposes of exposition, we pursue our objective of viewing sustainable IS alignment from a CAS and co-evolutionary perspective by describing the phenomena in the domains of enterprise architectures and IS development projects, domains that offer different types of insights into the applicability and utility of our theory. Recall, however, that conceiving of domains of alignment is a gross simplification of the multiple and multidirectional relationships that exist in an organization. Non-linear relationships engendered by multiple interacting agents result in causal intricacy that is not confined to organizational levels or domains of alignment. There is, therefore, no definitive way of describing activities in CAS.

The analyses that follow are illustrations of the co-evolutionary theory of IS alignment at work, not tests of the theory. We base our analyses on extant literature. We first examine enterprise architectures, followed by IS development projects.

4.1. Co-evolution in Enterprise Architectures

We define "enterprise architecture" as the business processes and associated IS/IT infrastructure that reflect the way in which the company supports its business (Ross, Weill, & Robertson, 2006, p. 47). We use the work of Ross et al. (2006) on enterprise architecture maturity, which, as far as we are aware, represents the most comprehensive analysis of enterprise architectures in the literature. Furthermore, it provides a uniform view across the spectrum of enterprise architectures, which allows us to examine their co-evolution over time.

For Ross et al. (2006), the key to IS support of the business focuses on "building a platform for execution". A platform for execution consists of an "operating model" and associated enterprise architecture. The notion of an operating model is based on the dimensions of business process standardization and integration (2 x 2), which results in four alternative models. The operating model provides a definitive view of the type of business processing that fits the organization and is implemented via an enterprise architecture. It is important, however, not to presuppose the situation with respect to a specific organization. Further, because of the need to support different business objectives, the different levels of IT architecture in a complex organization will not necessarily be at the same stage of maturity at the same time (Ross et al., 2006).

The enterprise architecture identifies the processes, data, technologies, and customer interfaces that support the chosen operating model. Ross et al. (2006) identify four stages of progressively increasing enterprise architecture maturity: 1) business silos, 2) standardized technology, 3) optimized core, and 4) business modularity. In 2005, 12, 48, 35, and 6 percent of companies were in Stages 1, 2, 3, and 4, respectively (Ross et al., 2006, Figure 4-1). These figures demonstrate that a large proportion of organizations are seeking to move through the continuum of stages represented by increased standardization and integration of both data and processes. That is, the majority of businesses today appear to prefer integrated IS delivered via a common platform.

In the sub-sections that follow, we examine the roles played by adaptive, administrative, and enabling IS management principles. Table 2 presents the distinguishing characteristics of enterprise architectures over time in terms of the co-evolution of the business and its IS/IT and the three adaptive IS management principles.

4.1.1. Adaptive IS Management in Co-evolving Enterprise Architectures

Transitions in the enterprise architecture maturity model result from a confluence of organizational needs and emerging technologies (see business and IS characteristics in Table 2). Hence, the transitions reflect co-evolution of the organization and its IS/IT, and therefore the adaptivity of its IS/IT. At a high level, an organization moves from a local to a global perspective in a continual learning process that involves significant adaptivity and therefore organizational change at each stage. We now examine the applicability of the three adaptive IS management principles to enterprise architectures.

Table 2. Adaptive Principles in Four Enterprise Architecture Maturity Stages

Stage	Characteristics		Adaptive IS management principles		
	Business	**IS**	**Match Co-evolutionary rates of change**	**Optimize self-organization**	**Synchronize exploitation and exploration**
1. Business silos	Local focus Local control	Decentralized systems Little integration of • IT platforms • Software systems • Data Local control (function-level)	Organizations that survive, by definition, have internal rates of change that match or exceed the rates of change in the environment Technological change has matched the rate of change in the environment. Human learning must be addressed to ensure rates of change in human systems match internal technological changes.	Local control →Self-organization possible for IS development projects	Exploitation of business unit technology Exploration likely

2. Standardized technology	Largely local focus
	Hybrid control
		Centralized IT platforms
		• Integrated hardware
		• organization-wide control
		Decentralized software systems
		• Function-level control
		Hybrid data
		• Decentralized
		  • Independent application systems
		  • Local control
		• Centralized
		  • Extracted and integrated in data warehouses
				Local control over some business processes
				→ Self-organization possible for locally-controlled processes
					Exploitation of common hardware and software
					Some exploration possible

3. Optimized core	Global focus Corporate control	Centralized IT platforms, software systems, data • Integration • Global control		Global control over IS/IT platform →Self-organization not possible	Exploitation of enterprise platform Exploration by reconfiguring global business processes
4. Business modularity	Global focus Largely corporate control	Hybrid systems: Centralized IT platforms, software systems, and data • Integrated • Global control Focused application systems • Not integrated • Local control		Global control over the majority of IS/IT Local control over customer-facing processes →Self-organization possible	Exploitation of enterprise platform Exploration by customizing customer-facing processes

4.1.1.1. Principle 1: Match Co-Evolutionary Change Rates in Enterprise Architectures

Because we use historical data to examine adaptive principles in the domain of enterprise architectures, there are few opportunities to capture explicitly the conditions existing at the time of the transitions identified in the enterprise architecture maturity model. However, by definition, organizations that survive match the co-evolutionary change rates they experience in the environment (March, 1991; Levinthal & March, 1993; Volberda & Lewin, 2003). That is, an organization that does not evolve at a rate sufficient to respond to changes in its environment cannot survive. These rates of change must be matched or exceeded in both the technological and human aspects of the organization. Therefore, if either the technological or human systems fail irrevocably, the organization cannot survive.

From the viewpoint of technological change, as organizations have transitioned through the progressive stages of enterprise architecture maturity, the pace of conducting business has increased. And, indeed, one of the major reasons for moving through the maturity stages is to meet the demands of a fast-moving world. The faster pace is supported by centralizing or integrating, first, the hardware platform in Stage 2 and then both processes and data in Stage 3. Hence, processing at Stages 3 and 4 is carried out in real-time on fully integrated enterprise architectures. Stage 4 promises further reduction in reaction time due to use of the Internet. Hence, increasing the adapativity of certain of the organization's IS supports co-evolution as the enterprise architecture matures.

From the viewpoint of human change, organizations may innovate technologically at a rate faster than the changes may be absorbed by the organization. Ross et al. (2006, p. 82) state: "Following a major ERP implementation, one plant manager reported: 'I feel like we turned out the lights but we keep trying to do our jobs anyway.' Another stated: 'It's like I'm standing on my head but still trying to manage'". Hence, while it is important that sufficient innovation take place so that the organization may keep abreast of environmental changes, it is also important that the organization be aware of, and respond to, the learning necessary to accomplish large-scale organizational change.

4.1.1.2.Principle 2: Optimize Self-organization in Enterprise Architectures

Self-organization may occur only when the enterprise architecture, or parts thereof, is under local control, which occurs in Stages 1 and 4 of the enterprise architecture maturity model and, to some extent, also in Stage 2 (see control under business characteristics in Table 2). In Stage 1, business silos, the information systems serve the specific needs of the business units. Business owners exert local control over the enterprise architectures, which they may develop as they see fit. While the architecture may serve the needs of a number of business unit users, business processes could be supported by self-organizing IS development teams.

In Stage 2, standardized technology, business units must often accept other than their preferred solutions. However, because business units retain some control over their business processes, some innovation may be possible. Hence, there is again the possibility, although reduced, of self-organization in IS development teams.

In Stage 3, the optimized core, organizations take an enterprise view of both their business and their IS. Hence, the organization's IS activities are controlled globally. However, while an organization may exploit an ERP to support its current business processes, it may also explore new processes that are embedded in the software. And, indeed, it is quicker to configure those processes than it is to write new software to support them. There is, however, little possibility of self-organization due to the need to maintain global control over business processes.

In Stage 4, the business modularity stage, organizations extend their business by modularizing and customizing specific processes. Typically, unique processes are added to the common, global platform to provide better customer interfaces and therefore better customer service. This stage accommodates both global standards and local customization. Addressing these unique business processes locally suggests that self-organization may be possible.

4.1.1.3. Principle 3: Synchronize Exploitation and Exploration in Enterprise Architectures

For effective co-evolution, exploitation and exploration are balanced so that the organization has a stable platform that may be exploited, while at the same time serving as the foundation for exploration and therefore innovation. Hence, the changes that occur in an enterprise transitioning from Stage 1 to Stage 4 may be characterized as moving from a stable state, representing exploitation, through an exploratory phase, to establish another stable state that is then exploited, and so on. For example, from Stage 1 to Stage 3, we see changes in the enterprise architecture to support, first, a standardized hardware platform (Stage 2), and then centralized processes and data (Stage 3). These changes take place in association with a transition from local to global business processes, which results in business unit managers relinquishing control over the local processes they were exploiting so that the company could explore the potential of a global platform.

The move from local to global processes, data, and the associated enterprise architecture manifests a change from exploiting the local focus in Stage 1 to exploring a global focus in Stages 2 and 3. The transition from Stage 3 to Stage 4 is characterized by changing the focus, at least in some part, from global to local processing. This transition exploits the global enterprise architecture in Stage 3 to allow certain aspects of its processing to be explored in Stage 4 to better fulfil local requirements, typically as add-ons or bolt-ons to enterprise technologies.

That stability (or exploitation) is essential for exploration in enterprise architectures is borne out by the evolutionary picture Ross et al. (2006) paint of the way in which enterprise architectures have matured over time. They stress the importance of completing the transitions in the order shown, of not trying to complete two stages at the same time or skip a stage, and of taking time to ensure that the necessary changes have been institutionalized. As just one example, they report that: “In several of the companies we spoke to, ERP implementations that tried to skip stages had to be halted or scaled back” (p. 81). The above are all examples of the need to balance exploitation and exploration in the development of enterprise architectures.

4.1.2. Management of Co-evolving Enterprise Architectures

We consider the three types of management together so that we can get a more complete picture of the way in which they interact in developing enterprise architectures. Table 3 presents the strength of the three types of management involved in the four stages of enterprise architectures in the enterprise architecture maturity model of Ross et al. (2006).

While we must take care not to presuppose the situation with respect to a specific organization, in general, the basic premise of our treatment of co-evolutionary IS alignment is that enterprise-wide aspects of IS, which form the backbone that supports the functioning of the organization—in this case, the enterprise architecture—may be best achieved via formal hierarchical coordination and control; that is, administrative IS management. From a business perspective, an organization may be made up of a number of distinct enterprises (e.g., a conglomerate), or it may represent a single enterprise. In either case, the multiple parts of the enterprise must play together at some point; that is, ultimately, formal hierarchical coordination and control define the boundaries of the enterprise. Where the organization draws the line with respect to formal control over its IS depends on the characteristics of the specific organization (as reflected in its operating model) and the environment in which it competes.

In Stage 1, where the focus is on functional areas rather than on the enterprise as a whole, the different functional areas are largely responsible for their own IS. The individual functional areas might, therefore, engage in adaptive IS management. And, as we have seen, there is also the possibility that IS project teams could self-organize. Such function-specific development is unlikely, however, to require enabling IS management due to the lack of an established corporate IS function.

Table 3. IS Management Principles in Four Enterprise Architecture Maturity Stages

Stage	IS characteristics	IS management elements	IS management		
			Administrative	Adaptive	Enabling
1. Busines Silos	Decentralized systems Little integration of • IT platforms • Software systems • Data Local control (function-level)	Hardware Software Data	Weak Weak Weak	Strong Strong Strong	Weak Weak Weak

2. Standardized Technology	Centralized IT platforms
	• Integrated hardware
	• organization-wide control
	Decentralized software systems
	• Function-level control
	Hybrid data:
	• Decentralized
	  • Independent application systems
	  • Local control
	• Centralized
	  • Extracted and integrated in data warehouses
		Hardware
		Software
		Data
			Strong
			Weak
			Weak
			Moderately Strong
				Weak
				Strong
				Strong
				Moderately weak
					Weak
					Strong
					Strong
					Moderately weak

3. Optimized Core	Centralized IT platforms, software systems, data • Integration • Global control	Hardware, software, Data	Very strong	Very weak	Very weak
4. Business modularity	Hybrid systems: Centralized IT platforms, software systems, and data • Integrated • Global control Focused application systems: • Integrated • Local control	Centralized IT platforms, software systems, data Integrated systems	Very strong Moderate	Very weak Strong	Very weak Strong

The notion of a common IS/IT platform becomes more important as co-evolution proceeds through Stages 2, 3, and 4. More and more IS/IT capabilities are derived from an increasingly integrated platform based on standardization and integration, which results in shared data and processes. Hence, the decisions on architecture must be made at high levels of the organization and cannot be driven from the bottom-up, that is, adaptively, by local personnel. There may, therefore, be little role for adaptive IS management in the high-level decisions made with regard to the IT platform and the overall direction chosen for the organization's business processes. This is the case in Stage 3, the optimized core, in particular.

Managing Stage 4, the business modularity architecture, requires negotiations between senior managers and IT executives to determine which processes and data will be standardized, which will be handled globally, and which may be developed locally (Ross et al. 2006). This is the role of enabling IS management. Further, project teams engaged in addressing business modularity may also engage in adaptive IS management; for example, as we have seen, they may be allowed to self-organize.

4.2. Co-evolution in IS Development Projects

The IS development project domain, as the name suggests, focuses on system development per se. Such projects are responsible for developing the IS to support the functioning of the organization. We illustrate co-evolution in IS projects in terms of agile IS development. We then address the management of IS development projects, in general, in a co-evolutionary context.

4.2.1. Adaptive IS Management in Co-evolving IS Development Projects

Complexity theory has been acknowledged as an appropriate theoretical foundation for explaining agile development (see, in particular, Conboy, 2009). We use Vidgen and Wang's (2009) analysis of an agile IS development project to illustrate the role of co-evolutionary and therefore adaptive principles in its execution. Table 4 presents the indicators Vidgen and Wang used to evaluate these principles in a project run by a team called Pongo. We present briefly the major points that emerged from their case study.

Table 4. Vidgen and Wang's (2009) Indicators of Adaptivity Principles on Agile IS Projects

Principle 1: Match co-evolutionary change rate	Principle 2: Optimize self-organization	Principle 3: Synchronize exploitation and exploration
1-1. How are user requirements changes monitored and tracked?	2-1. How is management distributed?	3. How are exploitation and exploration in software development synchronized?
1-2. How is the user requirements change rate matched or exceeded?	2-2. How are the capabilities of individuals maximized?	
	2-3. How are communications and collaboration facilitated?	

4.2.1.1. Principle 1: Match Co-evolutionary Change Rate in IS Development Projects

Vidgen and Wang (2009) use two indicators to evaluate this principle. The first indicator is "how are user requirements changes monitored and tracked?". Pongo's system development lifecycle consisted of project configuration, capturing initial user requirements, followed by several development iterations. The users identified precise business scenarios by writing "user stories" and acceptance tests. Information requirements and requirements for acceptance testing were defined and estimated for a weekly unit of work. Working software was produced and tested each week, which provided immediate feedback on requirements and project progress.

The second indicator is "how is the user requirements change rate matched or exceeded?". The "information unit" (user requirements to be addressed), typically 25 to 30 work units in length, was decomposed into units of work to be completed in a 30-minute work period. Once established, no changes to the information unit were to be made until the cycle was complete, except in certain, well-controlled instances. Any deviations from the weekly schedule were addressed in daily steering committee meetings.

Recall that the basis for Volberda and Lewin's stated principle was that "self-renewing organizations focus on managing requisite variety by regulating internal rates of change to equal or exceed relevant external rates of change (e.g., competitors, technology, customers, etc) (McKelvey, 2003)" (Volberda & Lewin, 2003, p. 2126). Volberda and Lewin go on to state that routines must be established "to measure, monitor, and track rates of change in all aspects of their environment and adjust their internal rates of change to match or exceed them" (see Section 3.2.2.1.1 of this paper). Both of the indicators in Vidgen and Wang's study focus, however, on performance in relation to the weekly plan; that is, they measure internal project progress. Because the authors' data relates solely to the conduct of the project per se, the indicator has nothing to say about systems co-evolving with their environments.

One cannot capture, therefore, the true intent of the principle of matching the internal and external co-evolutionary change rates in a study that addresses only the internal workings of a project team.

4.2.1.2.Principle 2: Optimize Self-organization in IS Development Projects

Given our observation above, it is important to note that self-organization in IS development projects may be addressed with reference to the project alone. The first indicator was "How is management distributed?". Vidgen and Wang use self-management (Stacey, 2003) to operationalize this indicator.

Close observation of every aspect of the process as it proceeded provided the necessary feedback for keeping on track. There was an expectation that leaders would emerge as appropriate. In addition, there were project manager roles, and a coach for the specific agile method the team used. Vidgen and Wang (2009) report that the project manager role appeared to focus more on facilitating self-management than on playing an active role in management.

The second indicator was “How are the capabilities of individuals maximized?”. In general, each team member could assume any role. The project manager assigned roles to team members following an open discussion regarding preferred tasks. Although team members generally chose tasks with which they were familiar, they could gain further expertise by signing up for a task with which they had little experience. They would then be paired with an expert in the area, thereby learning from the interaction. In a similar vein, when a team member completed a particularly difficult task, they were then immediately paired with another team member not experienced in the area to share the knowledge gained. Thus, team members had the opportunity to improve their skills on an on-going basis, thereby “maximizing” their capabilities.

The third indicator was “How are communications and collaboration facilitated?”. Pongo used multiple ways of communicating to encourage continual sharing and also learning. First, team members were co-located in a large open facility so that they could readily contact other team members. Second, regular meetings, both daily and weekly (planning, steering, feedback sessions), structured and facilitated team communication. Third, Pongo engaged in self-selected, pair programming, in which two team members (task owner and programmer) worked together on some unit of work, sometimes as small as one 30-minute interval. The knowledge shared was both technical knowledge and knowledge of who knew what, which helped in promoting self-organization and facilitating learning.

Thus, self-organization was a central focus of Pongo’s agile IS development project.

4.2.1.3.Principle 3: Synchronize Exploitation and Exploration in IS Development Projects

The project team adopted an innovative approach to embrace both exploitation and exploration during the project itself. Vidgen and Wang analyze a single indicator: “How are exploitation and exploration in software development synchronized?”. During the daily feedback sessions, the team focused on the development process, emphasizing what went well, and hence exploited basic processes. At the same time, two hours per day (two 30-minute periods both before and after lunch) were set aside for the exploration of new ideas, with one hour being focused on pursuing project-related issues. Both project-related and open study periods led to the emergence of ideas that the team might pursue.

Thus, this study presents an interesting example of how to foster both exploitation and exploration internal to an IS project.

4.2.2. Management of Co-evolving IS Development Projects

Because Vidgen and Wang (2009) focus on co-evolutionary or adaptive principles alone, they address only adaptive IS management. Therefore, we now take a broader view of the IS function, which incorporates all three forms of IS management. We use the general literature on IS project development in this analysis.

Most organizations use a combination of traditional and adaptive (agile) methods in their IS development projects (Vinekar, Slinkman, & Nerur 2006). These two approaches require different skills, different ways of working, different management approaches, and therefore quite different cultures (Nerur, Mahapatra, & Mangalaraj 2005). Furthermore, traditional IS development projects exploit existing knowledge and are subject to administrative IS management, which emphasizes hierarchical control and prediction. On the other hand, agile development projects explore new ways of developing IS and are subject to adaptive IS management, which emphasizes co-evolution and self-organization. It is important, therefore, to determine how the use of such apparently diverse methods may be reconciled within a single organization.

The organizational theory and learning literature suggests the notion of ambidextrous organizations (Tushman & O'Reilly, 1996; Vinekar et al., 2006) to manage two different types of activities, a situation that is exemplified in a manufacturing firm with separate business units for production and R&D activities. By analogy, the IS function could be viewed as an ambidextrous organization with separate units focusing on exploitation (traditional development approaches) and exploration (adaptive development approaches).

However, other considerations come into play for IS development. In particular, there is the role of enabling IS management, which mediates the activities of adaptive IS management in relation to formal, administrative IS management. Enabling IS management may be facilitated by having both types of development project ultimately managed within the same higher-level IS function (see Figure 2). A major role of that unit would be to determine the specific instances in which traditional development approaches would be appropriate and those in which agile development methods would best be applied. This overarching unit may therefore learn from the experiences of applying both types of methods, leading to better choice of methods for future development projects.

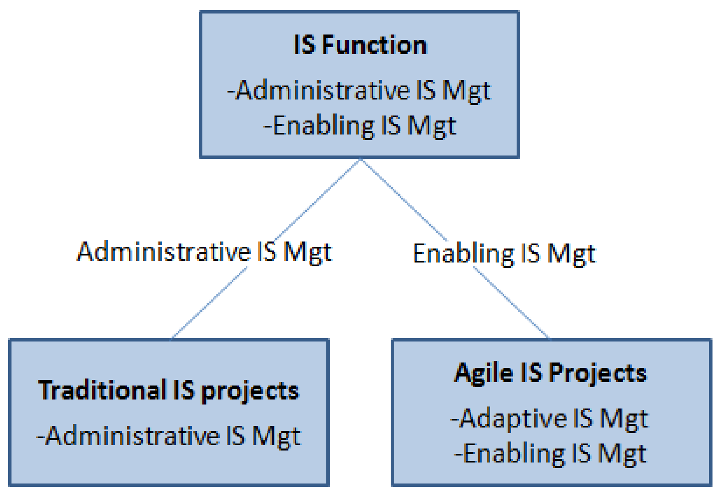

Figure 2. Organization of the IS function in Hybrid IS Development Organizations[1]

5. Discussion

We present a new theoretical approach to IS alignment, specifically to alignment that is sustainable over time. Sustainable IS alignment is becoming increasingly important in the current environment of globalization, dynamism, and uncertainty, an environment that also demands business agility. Our research question is: "How does sustainable IS alignment occur?". We base our co-evolutionary theory of sustainable IS alignment on the complexity theory worldview of complex adaptive systems (CAS), co-evolution, and emergence. Specifically, our theory views sustainable IS alignment as resulting when an organization's complex adaptive IS co-evolve with the complex adaptive organization they support.

We first discuss our theory, followed by the implications of our research for both research and practice.

5.1. Discussion of the Theory

Research into social systems, in general, and, from an IS perspective, organizations, is using the tenets of complexity theory to provide novel insights into the dynamics of social systems. The trend is away from a pure science model consisting of relatively few, linearly-related variables that result in

[1] Basic model adapted from Vinekar et al. (2006).

deterministic outcomes and toward a social science model consisting of multiple and multifaceted variables related in non-linear, and non-deterministic ways. The trend is, inevitably, away from a static, variance-based approach to research and towards a dynamic, process-based approach. Our co-evolutionary theory of sustainable IS alignment presents alignment as a dynamic, multi-faceted, and non-deterministic process.

The co-evolutionary theory of sustainable IS alignment is based on the notion that sustainable alignment results when an organization and its IS co-evolve, which, in turn, results when the organization's IS are developed in such a way as to facilitate their adaptation to the changing organizational goals. Because IS are organizationally based, our theory explains the role of adaptive IS in organizational settings. Our theory suggests that IS adaptivity must be tempered by top-down processes essential to established business organizations. We draw an analogy to Uhl-Bien et al.'s (2007) complexity leadership theory to identify roles for adaptive, administrative, and enabling IS management. Further, we illustrate the applicability and utility of our theory by examining the roles of co-evolution and IS adaptivity in both enterprise architectures and IS development projects.

Our research makes a number of contributions: 1) to IS research in general, 2) to prior research into IS alignment, 3) to research that uses the complexity theory worldview to address IS alignment, and 4) to research on achieving IS alignment.

First, our work on the complexity theory worldview contributes to IS research in general by recognizing that certain prior IS studies that take a bottom-up, adaptive, and emergent approach to certain phenomena may be explained using the complexity theory worldview. For example, we can use complexity theory to explain Ciborra's (1991) notions of tinkering and bricolage and Weick and Orlikowski's notions of improvization (Weick, 1993a; Orlikowski, 1996). The identification of an over-arching theoretical perspective for research of this nature affords us with a consistent view, as well as enabling the field to move forward more quickly, and more effectively, than would have been the case otherwise.

Second, our research makes a number of contributions to prior research on IS alignment. Conceiving of IS alignment as a process of co-evolving CAS aids the IS research community to come to terms with a number of the issues that have plagued the study of IS alignment over an extended period of time.

- Viewing alignment as a snapshot has limited utility. Although alignment may be established at a given point in time, the organization changes continually in response to changes in the environment, in which case its IS may no longer be aligned to the organization's needs. Our research focuses explicitly on alignment based on an organization's changing needs, that is, on dynamic alignment. Our theory therefore responds to the desire of the IS community to address IS alignment as a dynamic process, a desire that has prevailed since the appearance of Henderson and Venkatraman's strategic alignment model in 1993.

- Although prior IS alignment research had been based largely on a small number of factors that interact linearly, and therefore predictably, certain researchers have recognized that IS alignment may be best viewed as non-deterministic in nature. For example, Chan (2002) states that alignment should be viewed not as "a state, but a journey—one that is not always predictable, rational, or tightly planned" (p. 98). Our research responds to this issue by developing a theory of IS alignment that is based on alignment as a co-evolutionary and therefore non-deterministic process.

- Framing IS alignment as the co-evolution of the organization and its IS allows us to address what is arguably the key issue for IS alignment: how sustainable IS alignment occurs (reflecting our research question). Any IS change takes place to meet the goals of the organization as it evolves over time in response to its changing environment, thereby serving to align the IS with the needs of the organization. The IS alignment that results from the co-evolution of the organization and its IS is therefore sustainable. It is our belief that, rather than IS alignment per se, sustainable IS alignment is the Holy Grail that the IS community has long sought. Yet sustainable IS alignment has largely been ignored by IS researchers to date.

- Further, in examining the role of IS adaptivity in sustainable IS alignment, it is apparent that there are significant signs of evolving enterprise architectures and of the increasing use of adaptive structures, methods, tools, and techniques in IS projects. While a number of IS researchers have addressed IS adaptivity in terms of IS projects, particularly in terms of agile development, there have been few attempts to address adaptivity comprehensively throughout the organization. Our research is, for example, the first of which we are aware to address the evolution of enterprise architectures.

Third, our research also contributes to prior research on IS alignment that is based on the complexity theory worldview. To the best of our knowledge, no prior study that takes a complexity theory perspective on IS alignment has examined the need for both adaptive and traditional IS management. For example, the two studies of which we are aware that use the complexity theory worldview eschew the need for any kind of traditional management. However, because established organizations are supported by formal administrative processes and hierarchies, IS and the organization cannot co-evolve without management intervention (i.e., without some form of hierarchical control). In established organizations even today, therefore, formal, top-down organizational processes and bottom-up, emergent or adaptive processes that foster business agility co-exist.

Fourth, our research makes contributions with regard to achieving IS alignment. A number of authors have stated that there has been insufficient research into the issue of achieving alignment (see, for example, Chen, Sun, Helms, & Jih, 2008; Hirschheim & Sabherwal, 2001; Van Der Zee & De Jong, 1999). In our examination of adaptivity in the development of enterprise architectures and IS development projects, we found signs of significant use of the three forms of management in our theory: adaptive, administrative, and enabling IS management. Our theory therefore provides researchers with an overarching perspective on how to achieve sustainable IS alignment.

Fifth, our co-evolutionary theory of sustainable IS alignment also has implications for large-scale IS failures. When IS development is viewed as a co-evolutionary process, incremental changes are made to an organization's IS. Incremental changes made in the context of organizational needs would be made on a regular basis, drastically reducing, if not eliminating, the need for revolutionary change. Hence, there is less likelihood of serious IS failures when issues are dealt with as they arise.

5.2. Implications of the Theory

We now present implications of our co-evolutionary theory of sustainable IS alignment for both research and practice.

5.2.1. Implications for Future Research

Further research may be undertaken based on our theory. First, research might focus further on the concepts in the theory. In examining Volberda and Lewin's (2003) adaptive IS management principles in this research, we have noted that, while optimizing self-organization is essentially a within-unit indicator, and synchronizing exploitation and exploration may be interpreted as such, matching the co-evolutionary change rate describes the relationship between the internal and external environments. Hence, data describing the unit in the context of its environment is required to address the latter principle.

Second, the above observation has implications for the choice of research method; that is, study of these three principles is not equally effective across methodological approaches. Because of its bottom-up, emergent nature, self-organization may only be evaluated definitively in a case study setting, as, for example, in Vidgen and Wang's (2009) study of an agile IS development project. On the other hand, self-organization may only be inferred in retrospective studies, as in our examination of Ross et al.'s (2006) longitudinal analysis of enterprise architecture maturity.

Research therefore needs to be conducted to identify and formalize appropriate indicators for different types of research methods. Another way of approaching such research would be to specify a more complete set of indicators (see, for example, McKelvey, 2004), and to allow researchers to choose indicators appropriate to their research questions.

Third, as we state through this paper, our analyses of enterprise architectures and IS development projects serve as illustrations of the applicability of our co-evolutionary theory of sustainable IS alignment. Our theory therefore needs to be subjected to formal testing. As we see above, choices will need to be made on the concepts used, which depends on the specific focus of the study, and therefore the chosen research method.

Fourth, research might be conducted to further our understanding of various parts of the theory. For example, the following types of phenomena might be studied:

- We have seen that it is necessary to understand the internal structure and functioning of the IS only when a system can no longer adapt to changes in its environment. Research could therefore be conducted to determine the characteristics of IS that are critical to the adaptation process.

- Further, we have seen that just a few characteristics of the system's environment (the organization and its external environment) may result in the need for the organization's IS to adapt. Research is, therefore, also needed to identify the factors that are likely to result in changes to the artifact's internal structure and functioning. Magnitude of the organizational change to be addressed, for example, may be one such factor.

- The notion that sustainable IS alignment results from combining IS adaptivity with appropriate managerial controls provides a platform for further research on how to maintain sustainable IS alignment over time.

- Research needs to be conducted into the circumstances in which systems in all domains of alignment throughout the organization are better addressed top-down and those in which they are better addressed bottom-up. Because this type of decision may be influenced by the chosen operating model of the specific organization, future research could also investigate whether there are issues specific to certain types of operating models.

- Future research could address ways in which adaptive and enabling IS management may be facilitated in an environment in which formal and adaptive processes co-exist. Related research could also focus on better defining the roles and responsibilities of the three types of IS management.

Fifth, research is now starting to appear on the role of control theory in an agile IS development environment; see, for example, papers by Maruping, Venkatesh, and Agarwal (2009) and Harris, Collins, and Hevner (2009). Further research needs to be conducted to determine the relevance of control theory to IS adaptivity within the complexity theory worldview.

Finally, describing the phenomenon of IS alignment theoretically lays the foundation for a normative theory that prescribes how sustainable IS alignment may be brought about. Future research might develop a normative theory that provides the foundations for developing approaches to achieving and sustaining IS alignment, based on our explanatory theory of IS alignment.

5.2.2. Implications for Practice

From a practical perspective, first, the CAS view of organizations and IS presented here offers managers new ways of responding to environmental changes, both organizational and IS, that are likely to be more effective than traditional approaches, and therefore to result in sustainable IS alignment (as well as business agility). As we see in this paper, this is a particularly important issue given the dynamic world in which we live.

Second, practice must develop ways of balancing what needs to be controlled against what may be allowed to emerge. This situation will, as we have noted, differ for each organization, and for different parts of the organization, as noted earlier. A specific situation depends on the competitive environment in which a given organization finds itself, the associated pace of change (and therefore the need for innovation and adaptation), and the inherent characteristics of the business itself. This situation applies to organizations, IS, and to IS phenomena, including sustainable IS alignment.

Third, managers also need to be aware of the types of IS management (administrative, adaptive, and enabling) that are essential in managing IS adaptivity effectively. Often, the best outcomes arise via autonomy, empowerment, and self-organization rather than from controlling the actions of others. However, the formal nature of established organizations demands that, at some level, there be hierarchical control (administrative management). Managers need to balance control and emergence (exploitation and exploration) so that the organization does not become too rigid (too much control) or result in chaos (too much emergence). Again, this situation applies to organizations, to IS, and to IS phenomena, including sustainable IS alignment.

6. Conclusion

The IS research community has long sought to pursue alignment as a dynamic, multi-faceted, and non-deterministic process. We respond to this call using the complexity theory worldview to present the co-evolutionary theory of sustainable IS alignment, an explanatory theory of how sustainable IS alignment occurs. Our theory suggests that sustainable IS alignment occurs when the organization's IS co-evolve with the organization so that they support the organization in its efforts to meet its goals. The theory further recognizes that for an organization to succeed it must engage in both informal, adaptive activities as well as formal, administrative activities.

Because co-evolution that supports IS alignment results when an organization's IS change or evolve to support the changes that occur in the organization, our co-evolutionary theory of sustainable IS alignment focuses on enabling adaptive IS processes. The co-evolutionary theory of sustainable IS alignment consists of adaptive IS management principles and the formal administrative and enabling IS management that support an organization pursuing its established operations while exploring further initiatives. Each organization determines those parts of its function that need to be controlled and those parts that may be allowed to evolve.

We illustrate the effectiveness of our co-evolutionary theory of sustainable IS alignment by examining the diverse domains of enterprise architectures and IS development projects. We hope that focusing attention on how sustainable IS alignment occurs will aid in moving forward both IS research and practice.

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