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Research article

Using coevolutionary and complexity theories to improve IS alignment: a multi-level approach

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Abstract

The misalignment of information systems (IS) components with the rest of an organization remains a critical and chronic unsolved problem in today's complex and turbulent world. This paper argues that the coevolutionary and emergent nature of alignment has rarely been taken into consideration in IS research and that this is the reason behind *why IS alignment is so difficult*. A view of IS alignment is presented about organizations that draws and builds on complexity theory and especially its focus on coevolution-based self-organized emergent behaviour and structure, which provides important insights for dealing with the emergent nature of IS alignment. This view considers Business/IS alignment as a series of adjustments at three levels of analysis: individual, operational, and strategic, and suggests several enabling conditions – principles of adaptation and scale-free dynamics – aimed at speeding up the adaptive coevolutionary dynamics among the three levels.
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Introduction

Despite years of cumulative research, information systems (IS) alignment remains one of the leading areas of concern for business executives and has been constantly and repeatedly ranked as the most important issue facing corporations since the mid-1980s. Valuable research has been undertaken to establish a strong alignment between IS and organizational objectives and several alignment levels have been suggested to impact organizational outcomes, performance, and competitive advantage (Kearns and Lederer, 2000; Tallon *et al*., 2000). These include alignment between Business[1] and IS strategies, Business and IS planning (Earl, 1989), IS and organizational infrastructures (Ein-Dor and Segev, 1982), integration of IS and Business domains, among others. While this significant body of work has advanced our understanding of the IS alignment phenomenon, there is a tendency to focus upon simple cause–effect deterministic logic that favours short term over sustained alignment. This logic ignores the multi-faceted and coevolutionary nature of IS alignment and the complex mutual influences between IS and various organizational domains that maybe operating simultaneously over time.

In contrast, we view alignment as a continuous coevolutionary process that reconciles top-down 'rational designs' and bottom-up 'emergent processes' of consciously and coherently interrelating all components of the Business/IS relationships in order to contribute to an organization's performance over time. We argue that the coevolutionary and emergent nature of alignment has rarely been taken into consideration in IS research and that this is the reason behind *why IS alignment is so difficult*. In this paper, we address these limitations and present a view of alignment that draws and builds on coevolutionary theory (McKelvey, 2002). Our re-examination leads to a model for analysing the nature and role of IS alignment with organizations that constitutes a coevolutionary theory of IS alignment at three levels of analysis (individual, operational, and strategic). IS alignment via coevolution can be sped up if IS managers more explicitly keep the First Principles of Efficacious Adaptation in mind. The activation of the Principles can be further enhanced by taking advantage of several scale-free theories from complexity science.

This paper is structured as follows. In the next section, we review the main problems associated with current conceptualizations of IS alignment. This is followed by an overview of coevolutionary theory and its potential contribution to IS alignment. We then introduce our coevolutionary framework of IS alignment. Our framework suggests the coevolution of IS with the organization at three levels:

1. Coevolution of IS infrastructure with users needs – Individual level.
2. Coevolution of the IS department with the Business – Operational level.
3. Coevolution of IS strategy with Business Strategy – Strategic level.

Each of these levels is suggested to interact with the others and several critical enabling conditions are suggested to favour this coevolution at different levels.

IS alignment: the causes of the problem

Confusion and disagreement over the relevance of a structured strategy process

Traditionally, the literature on IS alignment referred to as 'strategic alignment' suggests that the effect of IS on performance will depend on the 'fit'[2] between IS strategy and corporate strategy. This presupposes, however, that IS plans are designed so as to integrate IS strategies with Business strategies. Baets (1992) describes top-down strategic planning models as methods aimed at using IS strategically in organizations. IS planning is the process of establishing objectives for organizational computing and identifying potential IS applications that an organization should implement (Teo and King, 1997; King, 1988; Earl, 1989). The essence of these models is that Business strategy must be analysed, and from this, an IS strategy follows.

However, despite linking Business strategy with IS strategy – mainly through defining detailed IS strategy plans – alignment continues to disappoint and the use of these preconceived strategic models has been challenged for several reasons. In particular, they assume mainly that alignment may be tightly planned. Instead, experience shows that alignment is not a 'state', but a journey that does not unfold in predictable ways (Sabherwal *et al.*, 2001; Chan, 2002).

Ciborra concludes that the achievement of competitive advantage from the deployment of IS is due more to serendipity and improvization than from prepensive formal planning. He argues that:

> IS strategic plans have been around for years, and their link with the Business strategy should have granted, though indirectly, some form of alignment. Often they have not, so there must be still an open problem; many cases of successful Strategic Information Systems seem to show that tinkering, not conscious alignment was at the origin of (ex-post) successfully aligned IS applications (Ciborra, 1994, 70).

Orlikowski similarly characterizes technology change and adaptation in organizations by improvization – as opposed to the classical view of change as a process of managerial planning, design, and intervention. In characterizing improvization in organization design, she quotes Weick, saying:

> [Plans]…tend to be emergent and visible only after the fact. Thus, the design is a piece of history, not a piece of architecture… . Design, viewed from the perspective of improvisation, is more emergent, more continuous, more filled with surprise, more difficult to control, more tied to the content of action, and more affected by what people pay attention to than are the designs implied by architecture (Orlikowski, 1996, 348).

Indeed, IS plans are subject to change as the approval of a proposed investment is only the starting point for a continually widening gap between stated objectives and the realities of today's changing environment. Unforeseen happenings, failed promises, and human errors cannot be included even in the best-laid plans. Thus, the disconnect often lies between what is assumed at the conception of a project and what is discovered during and after execution.

Rapid change requires flexible and creative strategies – characteristics that, according to Hamel (1996, 2000) are seldom associated with formalized planning. Grant (2003) characterizes strategic planning as consisting of 'planned emergence' that reconciles 'rational design' (top-down) and 'emergent process' (bottom-up) approaches to strategy formulation. This corresponds closely to Brown and Eisenhardt's (1997) concept of 'semistructures': planning systems that create an organizational structure, a fixed time schedule, and defined goals and responsibilities, while offering considerable freedom for experimentation, entrepreneurship, and initiative at the business level. This suggests that defining detailed strategic plans to integrate IS and Business strategy – *strategic level* – is important but not enough for alignment to be achieved. IS and Business strategy should coevolve mutually to respond to changes in the business environment. This involves a continuous process of adaptation and learning along with some degree of experimentation (Van der Zee and De Jong, 1999).

Overemphasis on reaching balance and stability between IS and organizational infrastructures

In addition to the failure of preconceived attempts at high-level business strategy and IS fit, the literature on IS infrastructure alignment often treats it as a static end state aimed at balancing the different components of IS and organization infrastructure. This view holds that to transform strategy into daily business and leverage IS functionality, organizational and IS infrastructures should be integrated and aligned. Among the alignments studied at this level, which we refer to as *operational alignment*, are the fit between IS structure and organizational infrastructure (Ein-Dor and Segev, 1982), competitive strategy and IS structure (Tavakolian, 1989), IS structures with business structures, and strategy and IS infrastructure (Papp and Luftman, 1995), with a predominance of the formal structural[3] alignment over the informal dimension. These

Table 1 Alignment components

Alignment dimensions	*Definitions*	*Components*
Strategic dimension	Alignment of IS strategy with Business strategy	IS strategy, Business strategy strategic planning
Operational dimension	Alignment between organizational structure and IS structure Alignment between actor's communication and degree of involvement with IS strategy domains	Locus of responsibility Decision-making rights Deployment of IS personnel Organizational actors values Communication with each other
Individual dimension	Alignment between IS infrastructure and user's needs	Understanding of each other IS infrastructure Users expectations and needs

scholars attribute deterioration in IS alignment to changes in broad organizational context variables. They argue that IS should conform to context variables such as organizational decision-making structure, managerial philosophy, and organizational form (McFarlan *et al.*, 1983; Cash *et al.*, 1992).

These studies, however, have not effectively integrated notions of IS infrastructure with organizational infrastructure components as they fail to consider the architecture of IS as a key factor in aligning information technology with organizational components – see Table 1.[4] IS infrastructures include platform technologies (hardware and operating systems), network and telecommunications technologies, databases, and a variety of shared services – such as e-mail, universal file access, videoconferencing, and teleconferencing services. These provide the foundation for enabling sustained IS assimilation in business activities (Weill and Broadbent, 1998). Building a technology infrastructure that will support existing IS applications while remaining responsive to external changes in information technology is not only key to alignment but also key to long-term enterprise productivity (Brancheau *et al.*, 1996).

However, the IS artefact in IS alignment literature tends to disappear from view, be taken for granted, or is presumed to be unproblematic once it is built and installed (Orlikowski and Iacono, 2001). These authors further note, 'We have tended to take information technology (IT) for granted in IS research, and we now need to turn our attention to specifically developing and using interdisciplinary theories of IT artefacts to inform our studies' (p. 130). Ciborra (1997) agrees on the fact that the IS component of alignment used – the object of IS alignment – is often taken for granted; he suggests reconsidering the role played by technology, looking at technical systems as 'organisms' with a life of their own, an idea that drastically changes the traditional notion of IS alignment.

Indeed, use of words such as adaptation and flexibility explicitly presumes that the world is too dynamic for a static order between IS infrastructure and the different organizational infrastructure components. Further, while organizations that may adapt their strategy or organizational infrastructure may enjoy an advantage over others who fail to adapt, success will ultimately be contingent upon whether IS is flexible enough to support a reconfigured business strategy that itself keeps pace with a firm's ever-changing competitive context. We will refer to this latter dimension of alignment level as *individual* where IS infrastructure should coevolve with users needs. This implies that IS alignment is an ongoing coevolutionary process that may benefit from both IS flexibility and strategic and organizational flexibility. Orlikowski, following Markus and Robey (1988), suggests that there is much potential in seeing technologies and organizations as mutually dependent and dynamically emergent.

The traditional literature, as we have shown earlier, however, treats both IS and organizational components as static entities that can peremptorily be controlled. Two alternatives have been suggested: the first recognizes that alignment is incremental and should be viewed as a process of slow adjustments. The second draws on the punctuated equilibrium idea from biology,[5] which holds that relatively long periods of stability (equilibrium) are punctuated by short jolts of dramatic change (revolution). Orlikowski (1996, 64) criticizes this latter approach as being mainly based on stability and does not account for incremental emergent change. She notes:

> Both the punctuated equilibrium model and its hybrids raise difficulties for the new organizing discourse because they are premised on the primacy of organizational stability. Whether improving an existing status quo or shifting to a new one, the assumption underlying these models is that the preferred condition for organizations is some sort of steady state or equilibrium.[6]

Sabherwal *et al.* (2001) suggest further that the incremental aspects can lead to complacency and inertia. An overemphasis on incremental infrastructure alignment could constrict an organization's outlook, inhibit its recognition of alternative perspectives, and reduce its ability to recognize and respond to the need for change (Miller, 1996). Alignment facilitates short-term success, which could lead to inertia, which in turn could lead to failure when market conditions shift suddenly (Tushman and O'Reilly, 1996).

Instead, the different components of alignment are not in a stable state, but in continuous and dynamic interaction with each other and with changing competitive context. In other words, alignment is an emergent process of dynamic interactions between the three levels of analysis suggested (strategic, operational, and individual) with the subsequent

Table 2 Alignment definitions

Authors	*Definitions*
Reich and Benbasat (1996)	The degree to which the IT mission, objectives, and plans support and are supported by the business mission, objectives and plans – alignment – is conceptualized as a state or an outcome
Chan *et al.* (1997)	Strategic alignment occurs when IS functions are amalgamated with the most fundamental strategies and core competencies of the organization
Hirschheim and Sabherwal (2001)	The notion of strategic alignment is based on three arguments: (1) an organization's performance is related to its attaining the appropriate structure and capabilities to execute its strategic decisions; (2) alignment is a two way street: the business strategy influences IT and IT influences business strategy; and (3) strategic alignment is not an event but a process of continuous adaptation and change
Broadbent and Weill (1993)	The degree of congruence of an organization's IT strategy and IT infrastructure with the organization's strategic business objectives and infrastructure

need for one or the other to be adjusted to sustain alignment.

Based on our analysis, we suggest that IS alignment is a continuous coevolutionary process that reconciles top-down 'rational designs' and bottom-up 'emergent processes' of consciously and coherently interrelating all components of the Business/IS relationship at three levels of analysis (strategic, operational and individual) in order to contribute to an organization's performance over time.

Our definition diverges from previous definitions – shown in Table 2 – in a number of ways:

- We clearly opt for alignment as a continuous process, involving continuous adjustment, rather than an event with an end point after which an organization can return to a state of equilibrium.
- We take all the components of the Business infrastructure/IS relationship into account; we do not confine alignment to the strategic level.
- We do not restrict alignment to managerial processes, but include design processes as well; by this, we simultaneously distance ourselves from the vision in which the management is able to determine every single aspect of the Business/IS relationship.
- We do not strive 'by definition' for harmony or balance between the different elements of the Business/IS relationship, since we assume that consciously introduced and/or sustained lack of balance is the motor of many organizational innovations.

IS alignment: lessons from coevolutionary dynamics

After a brief discussion of coevolution in organizations, we apply our coevolutionary perspective to IS alignment at three organizational levels. We conclude by focusing on several ways for improving IS alignment.

Coevolution in organizations

Our review of suggested alternatives to rational, top-down, static IS designs shows IS scholars calling for a more dynamic, interactive, mutual adaptation approach (e.g., Ciborra, 1997; Orlikowski, 1996; Van der Zee and De Jong, 1999), in short, coevolution. Our coevolutionary perspective allows us to frame the process of mutual adaptation and change between Business and IS strategies, Business and IS departments, and IS infrastructure and business users not just as a matter of alignment but as a dynamic interplay of coevolving interactions, interrelationships, and effects – summarized in Figure 1. Thus, we adopt a holistic rather than a bivariate conceptualization of alignment so as to highlight the complex and interrelated nature of the relationship between the different components. IS alignment, thus, is conceptualized as a process of continuous adaptation and change between these different components – building from Ciborra's 'organismic' view.

The term coevolution was coined by Ehrlich and Raven (1964) in their study of butterfly/plant coevolution towards symbiosis. Kauffman (1993, 237) observes that all 'evolution' is really coevolution:

> The true and stunning success of biology reflects the fact that organisms do not merely evolve, they coevolve both with other organisms and with a changing abiotic environment.

He argues that coevolution is at the root of self-organizing behaviour, constant change in systems, the production of novel macro structures, and non-linearities.

McKelvey (1999) considers coevolution and competitive behaviour of firms, defining coevolution as 'mutual causal changes between a firm and competitors, or other elements of its niche, that may have adaptive significance' (p. 299). He stresses that coevolution is a multi-level phenomenon and that it is necessary to 'take a more emergent natural systems perspective and pick parts naturally emerging as evolutionarily significant (those most likely to change, which offer selective advantage for the firm as a whole)' (p. 298). Lewin and Volberda (1999) identify five properties of coevolutionary models of strategic management and organizational adaptation research: multi-levelness, multi-directional causalities, non-linearity, feedback and interdependence between organizations, and history dependence – see Table 3. Mitleton-Kelly and Papaefthimiou (2000) adopt a multi-level analysis, looking at the interaction: among individuals, between individuals and IS, between Business and IS domains, and between the organization and its environment. Peppard and Breu (2003) also apply coevolutionary theory to Business/IS strategic alignment.

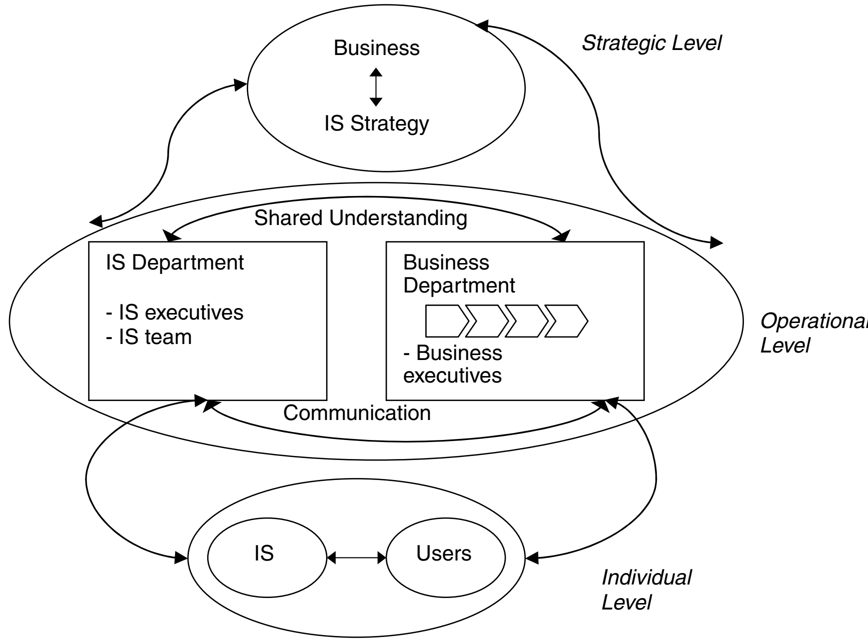

Figure 1 Coevolutionary IS alignment.

Table 3 Properties of coevolutionary models Lewin and Volberda (1999)

Essential properties	*Description*
Multi-level effects	Coevolutionary effects take place at multiple levels within firms and between firms and their environment
Multi-directional causalities	Coevolutionary effects result from multi-directional causalities within a complex system of relationships where changes in variables are caused by changes in others
Non-linearity	Coevolutionary effects are not tractable through a simple cause–effect logic of linear relations between independent and dependent variables
Positive feedback	Actions and interactions between firms and their environment are recursive and result in interdependencies and circular causality

In our framework, multilevel aspects can be seen where IS should be, on the one hand, aligned with user's needs (Individual level), between Business and IS departments (Operational level), and between Business and IS strategies (Strategic level), and on the other, adapted to the changing external environment. As the environment continues to change (slowly or rapidly), changes that the system has to address if it is to remain effective become evident, as do tensions calling for aligning IS to a new set of organizational needs. Multi-directional causalities appear in several areas where we see coevolution at the different levels suggested, but also between different levels of analysis. Further, non-linear relationships appear between IS and Business domains and among the infrastructure components within each. Coevolution may also appear when a change in the external environment occurs requiring changes in both IS and organizational components. Finally, positive feedback and interdependence appear in our framework where change in one level requires adjustments in adjacent levels to keep pace with the coevolutionary nature of IS alignment. This positions IS alignment as the coevolution of interacting subsystems – our three levels – that exist in some environment, where perturbations to one subsystem or to the environment create the possibility for evolution elsewhere in the system. Alignment, then, is the series of coevolutionary moves that makes IS aligned over time.

Coevolutionary IS alignment

In the following subsections, we develop our coevolutionary theory of IS alignment, taking a three-level coevolutionary perspective: (1) *Strategic level* – coevolving IS and Business Strategies; (2) *Operational level* – coevolving Business and IS domains; and (3) *Individual level* – coevolving IS infrastructure with users needs. Figure 1 illustrates the three levels of analysis of our framework, showing as well relationships between the different levels of analysis.

Strategic Level – coevolving IS and business strategies

IS alignment is not an event but a coevolutionary and emergent process since strategies continually change, requiring an adaptation at different levels, strategic, operational and individual. Indeed, as business strategy changes, IS strategy must change in parallel. This cannot be achieved just by relying on top-down planning with little emphasis on the emergent nature and necessity of bottom-up planning for alignment. Segars and Grover (1999) distinguish among alternative IS planning approaches by examining the level of rationality and adaptation in organizations. They characterize rationality as a comprehensive, formalized process, with a top-down flow and a focus on control. Adaptation is evident where there are frequent planning cycles and broad participation profiles. Organizations rating highly on both rationality and adaptation are found to be the most successful in IS planning, when one of the success measures is alignment. Other authors suggest that – in addition to scope/comprehensiveness – flexibility, and adaptability of the planning system are important factors in IS alignment (Chakravarthy, 1987).

Operational Level – coevolving IS and Business departments
As for aligning Business and IS departments, experience suggests that in many organizations where misalignment occurs, business managers and IS planners are unable to express themselves in common language, one necessary to cope with the absence of rationality and analysability. Consequently, successful links between Business objectives, IS strategy, and underlying IS architecture are insufficiently built. In short, they do not understand each other's complexities. Therefore, tightly aligned business and IS domains need continuous coordination and communication between the two poles of the duality, Business and IS. In order to achieve this, both Business and IS must form effective collaborative partnerships at all levels. They need to define and gradually develop understanding of each other's domains; they need to set up agendas where they discuss and coordinate actions related to continually sustaining IS alignment. Only through continuous adjustments between the two entities – Business and IS – that alignment can be sustained. Otherwise, if Business and IS strategies change, and Business and IS departments are not aligned, business executives' ignorance of the potential contributions of IS, and the IS executives lack of knowledge about Business strategy, may lead to an effort to align IS with an obsolete Business strategy, not with the new one.

Individual Level – coevolving IS infrastructure with individual users' needs
It is largely acknowledged that for an IS infrastructure to be effective, it should be aligned with individual users' requirements and needs. The most common conception of the user in IS research is one of an individual with well-articulated preferences and the ability to exercise discretion in IS choice and use, within certain cognitive limits (Lamb and Kling, 2003). This conception, however, has been challenged by several researchers, who argue that, within a typical firm, individuals rarely have the opportunity to choose the system they use (Karahanna and Straub, 1999). Instead, they select from a set of resources designated at the organizational level. Lamb and Kling (2003), in addition, point to the fact that users do not hold the same view of themselves that IS analysts do, and they do not like to be referred to as users. They do not even think of themselves as primarily having anything to do with the computer at all. They see themselves as professionals, working with others, and using computers in support of these interactions. This often results in a resistance to the system being implemented. User involvement, participation, and recently partnering with IS staff in the system development process have been suggested so as to promote collaboration and enhance IS project performance (Jiang *et al*., 2006). Yet, even if an IS is developed to respond to actual user needs or even a segment of them, these needs often change with time, reflecting the evolutionary aspect that IS invariably has to eventually account for (Benbya and McKelvey, 2006). Indeed, as users become competent in using an IS, they often see new ways of doing things and dream up new things to do with the IS. These new ideas change the organization and its perception of what is required from its IS. If these changes cannot be easily incorporated in the IS, the users become frustrated and dissatisfied with the system. The reality is, that to derive its expected benefits and remain aligned with users need, the IS *and* its users must continually coevolve.

Improving the coevolution of IS alignment: some principles

The adaptive success of coevolutionary dynamics rests on what McKelvey (2004) calls the *Seven 1st Principles of Efficacious Adaptation*. We use only five here. The following section describes how the coevolution of IS alignment can be favoured.

1. *Fostering coevolution*: Since we have already focused on the importance of positive feedback-based coevolution for effective IS alignment, we only mention it here briefly, as one of the 1st Principles. As complexity scientists find in their studies of new order creation, the possibility of positive feedback cycles allows some small instigating events to spiral into complex new structures that are adaptive responses to complex and turbulent environments (Arthur, 1988; Holland, 1998; Kauffman, 1993). But, coevolution may be either the negative feedback, equilibrium seeking, control system type process emphasized in general systems theory (Bertalanffy, 1968; Van Gigch, 1974), or a positive feedback process – what Maruyama (1963) terms 'deviation amplification'. We focus on the latter where alignment is a dynamic process, involving continuous adjustments between Business and IS at the three levels of analysis suggested, as they respond to changing environmental conditions. If negative feedback processes prevailed at the outset of agent interactions, they would simply revert to the initial 'square-one' state of existing order, if any. Or fall into inertia or equilibrium.

2. *Applying tension when and where needed:* Prigogine's Nobel Laureate work (Prigogine and Stengers, 1984, 1997) begins with Bénard's (1901) dissertation on fluid dynamics, which showed that at the '1st critical value' new structures (akin to a rolling boil in a teapot) emerge to speed up heat transfer. Prigogine discovered that these emergent 'dissipative structures'. as he called them, appeared as new forms of order serving the purpose of speeding up entropy production – which is to say, the emergence of order speeds up the kinds of physical order governed by the First Law of Thermodynamics (Newtonian mechanics) that then serve to more rapidly dissipate energy as called for by the Second

Law of Thermodynamics (Swenson, 1989). Tension can be applied to our three levels of analysis (strategic, operational and individual). At the strategic level, management commitment to IT and its championing of important IT initiatives imposes tension onto the other sub-levels. This tension can also motivate both the operational level (where IT staff and business units should form strong partnerships to generate value from IT investments), and the individual user level (where the selected infrastructure should respond to users' needs motivated by the imposed tension to use IT effectively so as to derive the expected benefits). This implies that IS/Business coevolution is instigated by adaptive tension imposing on interactions among overlapping sets of individual and group perspectives. Furthermore, as the broader environment and the intersecting stakeholder 'worlds' continue to change (slowly or rapidly), adaptive tension increases: changes that the system has to address if it is to remain effective become evident, as do tensions calling for aligning IS to changing organizational needs. Using a coevolutionary perspective allows us to frame this process of adaptive tension not just as a matter of alignment facilitating short-term success – which leads to inertia that in turn leads to failure when the environment suddenly shifts (Greenwood and Hinings, 1996) – but as a dynamic interplay of coevolving interactions, mechanisms and effects, all of which are set in motion by adaptive tensions (McKelvey, 2001, 2006).

3. *Improving requisite complexity*: Another condition favouring the coevolution of IS alignment is evolved complexity. This builds from Ashby's 'Law of Requisite Variety': 'Only variety can destroy variety' Ashby (1956, 207) – which Boisot and McKelvey (2005) update to the 'Law of Requisite Complexity'. Ashby's path-breaking work on cybernetics identified a key principle of system 'complexity', namely that in order to remain viable, a system needs to generate the same degree of internal complexity as the external complexity it faces in its environment. Essentially, external complexity – including 'disturbances' or uncertainty – can be managed or 'destroyed' by matching it with a similar degree of internal complexity. This requirement appears in the IS alignment literature as both the capacity to integrate dissimilar IS and business components as well as the ability of IS architecture to generate technical variety sufficient to fit changing environmental conditions. This requires, however, an IS infrastructure able to accommodate enough variety to adapt to its changing external environment. This is reflected in Evans (1991) flexibility typology component as the capacity of IS to continually mutate in metamorphic settings. Lycett and Paul (1999) argue that it is more realistic to postulate a 'reality' of systems continuously adapting to compensate for environmental perturbations. The larger the available counteractions (internal complexity) available to an IS, (1) the larger the set of perturbations it can compensate for; and (2) the larger the number of different environmental situations to which it can successfully adapt.

4. *Taking advantage of modular design*: Simon's (1962) classic essay on the 'architecture of complexity' articulates his design principle for modular systems. He argued that complex systems that are hierarchical – but which consist of 'nearly decomposable' subunits (meaning that they are mostly independent from top-down control or interdependencies with other subunits) – tend to evolve faster and toward stable, self-generating configurations, has been influential in the way modularity has been conceived. Simon's idea re-emerges as Weick' (1976) 'loose coupling' concept and more recently as modular production and product design (Sanchez and Mahoney, 1996; Schilling, 2000). This Principle applies in particular to IS infrastructure.

Schilling (2000) suggests that modularity is a continuum describing the degree to which a system's components can be separated and recombined. Modularity is, thus, the ability to easily reconfigure (add, modify, or remove) technology components by minimizing interdependencies among modules and is considered one of the most important dimensions in IS flexibility (Duncan, 1995). A higher degree of modularity consequently means a greater speed in developing new, or modifying existing, applications.

The ability of an organization to adapt its IS to changing business environments and create a mutually reinforcing pattern of evolving, tightly aligned Business strategy and IS capabilities will depend ultimately on whether IS has modular flexibility. Nelson and Nelson (1997) distinguish between two dimensions of flexibility, structural, and process. Structural flexibility refers to the characteristics of IS architecture – and includes mainly characteristics such as modularity and acceptance of change. Process flexibility refers to people's ability to make changes to the technology and includes the skills necessary for adaptation, change management, and coordination among business and IS people.

Allen and Boynton (1991, 435) contend that in many firms, IS are more disablers of flexibility than enablers; they write, 'IS efforts generally automate the status quo, freezing the organization into patterns of behaviour and operations that resolutely resist change'. While organizations may act on the other components of alignment, rigidity in the IS infrastructure leads to inertia and the inability to adapt effectively. Ross (2003) suggests that organizations must develop an IS architecture competency to dynamically adjust strategies and technologies and create a mutually reinforcing pattern of evolving, tightly aligned IS and business components.

5. *Speeding up the rate of change*: Fisher's (1930) work made a key link between variation and adaptation that is now all but axiomatic in the biological and social sciences. His basic theorem states: 'The rate of evolution of a character at any time is proportional to its additive genetic variance at that time' (quoted in Depew and Weber, 1995, 251). In other words, adaptation can proceed no faster than the rate that usable variation becomes available – for example, in the form of new knowledge, learning, innovation, networking, agent skills, etc. Evolution in the changing competitive environment to which an organization's strategy attends requires IS systems to be continually re-aligned so as to keep them in tune with its changing strategy, frequent communications and partnering between IS and Business levels, strong technical and business skills among IT staff, and strong IT skills among business staff. They also need to keep up with changes in the broader IT environment external to the organization. Therefore, it is necessary to keep IS components changeable enough so

that they can keep pace with a firm's evolving strategies and derivative coevolving changes in the various lower-level organizational infrastructure components, both Business and IS. This is particularly true in the case of uncertain, disruptive and rapidly changing environments. In this sense, the term dynamic refers to 'the capacity to renew competences so as to achieve congruence with the changing business environment' (Teece *et al*., 1997, 515). Recognizing that alignment 'is not an event but a process of continuous adaptation and change' (Henderson and Venkatraman, 1993, 5), the assignment of IS resources to capabilities must be continuously re-evaluated to prevent the organization slipping into a state of misalignment. To achieve this, however, necessitates speeding up the process of coevolutionary adaptations at the different levels suggested. For example, at the individual level where changes in user's requirements have been identified, IS and Business executives should increase the rate of gap reduction via quickened learning loops and real-time action on their feedback as the iterative process continues.

Using scale-free dynamics to improve IS alignment

Background on scale-free theory

So far, we argue that the adaptive success of the coevolutionary dynamics between Business and IS organizational components may be better assured if either Business or IS managers (or both) work to apply the underlying Principles that drive efficacious adaptation – we focus on five of the seven proposed by McKelvey. We have also discussed coevolution across three levels: interacting individual users with IS infrastructure, interacting organizational and IS sub-units, and the interaction of the prior two levels with top-level business strategy. Now we turn to how best to foster coevolution at multiple organizational levels.

The present-day tendency in organization studies is to apply lessons from different disciplines at different levels of organization, for example: psychology at the worker level, social psychology at the group level, sociology and anthropology at the organizational level, and population ecology or industrial organizational economics at the industry level. This complicates things for IS and other business practitioners. Complexity scientists offer a different approach. Merali (this issue) offers a good introduction to basic ideas in complexity theory.

We recognize three basic Schools of complexity science: (1) *European*: Prigogine and others' (e.g., Haken, 1977; Cramer, 1993; Mainzer, 1994), focus on adaptive tension and the first critical value of imposed energy in physical systems. Prigogine is famous for his 'dissipative structures'; (2) *American*: The Santa Fe Institute's focus on how new order arises in biological and social systems (Anderson *et al*., 1988; Pines, 1988; Cowan *et al*., 1994; Arthur *et al*., 1997). A key element, computational modelling, begins with Kauffman's work on 'spontaneous order creation' (1969, 1993), resulting from heterogeneous agents and connectivity (see also Merali, this issue); and (3) *Econophysics*: Here the focus is on how order creation actually unfolds once the forces of emergent order creation by self-organizing agents – such as biomolecules, organisms, people, or social systems – are set in motion. Key parts of this third aspect are *fractal structures*, *power laws*, and *scale-free theory*. We focus on scale-free theory.

Recognizing the many different disciplines extant in the natural and social sciences, in his opening remarks at the founding of the Santa Fe Institute, Nobel Laureate Murray Gell-Mann (1988) chose to focus everyone's attention on the study of '*surface complexity arising out of deep simplicity*'. Gell-Mann's phrase reawakened the search for scale-free theories – simple ideas that explain complex, multi-level phenomena (1988, p. 3). Brock (2000) goes so far as to say that '*scalability*' is the core of the Santa Fe vision – the idea that, for example, the coast of Norway appears jagged no matter what kind of measure is used: miles, kilometres, meters, or centimetres. No matter what the scale of measurement, the phenomena appear the same and result from the same causal dynamics.

Consider the cauliflower. Cut off a 'floret'; cut a smaller floret from the first floret; then an even smaller one; and then even another, and so on. Other than increasingly small size, each performs the same function and has roughly the same design as the floret above and below it in size. This feature defines it as fractal. Fractals can result from mathematical formulas – the very colourful ones figuring in Mandelbrot's '*Fractal Geometry*' (1982). *We are more interested in fractal structures that stem from adaptive processes* – like the cauliflower – in biological and social contexts. In fractal structures, the same adaptation dynamics appear at multiple levels. Andriani and McKelvey (2005) list 80 kinds of power laws, which are presumed indicators of fractal geometry, in physical, biological, social, and organizational phenomena. Stanley *et al*. (1996) find that, taken as a whole, manufacturing firms in the US show a fractal structure – a result confirmed by Axtell (2001).

Scale-free theories explain why fractals appear as they do. Although scalability may have been at the core of the Santa Fe vision, scale-free theories have only recently begun to be consolidated and featured collectively by the econophysicists (West and Deering, 1995; Stanley *et al*. 1996; Mantegna and Stanley, 2000; Newman, 2005; Newman *et al*., 2006; Sornette, 2006). Andriani and McKelvey (2006) give a more complete classification – they discuss 16 of them. The feature that sets scale-free theories apart from others is that they use a single cause to explain fractal dynamics at multiple levels. The earliest dates back to 1638 – Galileo's Square-Cube Law.

Scale free causes underlying efficacious coevolutionary adaptation

We began by outlining the IS alignment problem. We show that it is a coevolutionary process driven by changing competitive environments, top-level business strategy, interacting organizational and IS sub-units, and individual user needs. We then discuss the need for improving coevolutionary dynamics across these three organizational and interaction levels. We also argue that the coevolutionary dynamics may be enhanced or sped up by managing to make sure at least five of the 1st Principles are put into practice. Each of these, we hold, improves the adaptive success of the coevolutionary dynamics. Mostly, coevolution as we apply it is based on positive feedback. In this subsection, we focus primarily on theories about

Table 4 Scale-free theories underlying the 1st Principles of efficacious adaptation

1st Principles[a]	*Scale-free theories from the natural and social sciences*[b]
Deviation amplification: Maruyama	*Deviation amplification*: Two species mutually reinforcing the adaptive success of the other; the mutual reinforcement process leads to an exaggeration of outcome effects (Maruyama, 1963).
Tension: Prigogine	1. *Tension*: Exogenous energy impositions cause autocatalytic, interaction effects such that new interaction groupings form (Prigogine and Stengers, 1997). 2. *Spontaneous order*: Heterogeneous agents seeking out other agents to copy/learn from so as to improve fitness generate networks; with positive feedback, some networks become groups, some groups become larger groups and hierarchies (Lichtenstein and McKelvey, 2004).
Rate of genetic variance: Fisher	1. *Preferential attraction*: Given newly arriving agents into a system, larger nodes with an enhanced propensity to attract agents will become disproportionately even larger (Barabási, 2002). 2. ¼ *power law*: While energy-absorbing surfaces expand by the square-cube law, metabolic rate (energy) is governed by the ¼ power law because the rate of fluid flow is based on linear tubes (Kleiber, 1932).
Requisite variety (complexity): Ashby	*Least effort*: Word frequency is a function of ease of usage by both speaker/writer and listener/reader (Zipf's (power) Law); now found to apply to firms and economies in transition (Ishikawa, 2005; Dahui *et al*., 2006; Podobnik *et al*., 2006).
Near-decomposability: Simon	1. *Square-cube law*: Surfaces absorbing energy grow by the square, but organisms grow by the cube, resulting in an imbalance; fractals emerge to balance surface/volume ratios (Carneiro, 1987). 2. *Connection costs*: As cell fission occurs by the square, connectivity increases by $n(n-1)/2$, producing an imbalance between the gains from fission *vs* the cost of maintaining connectivity; consequently organisms form modules or cells so as to reduce the cost of connections (Bykoski, 2003). 3. *Self-organized criticality*: Under constant tension of some kind (gravity, ecological balance), some systems reach a critical state where they maintain stasis by preservative behaviors – such as Bak's small to large sand-pile avalanches – which vary in size of effect according to a power law (Bak, 1996).

[a]We use five out of seven of McKelvey's 1st Principles (all are discussed in Benbya and McKelvey, 2006).
[b]We use nine out of 16 scale-free theories discussed by Andriani and McKelvey (2006).

different kinds of positive feedback, what their scale-free basis is, and how each scale-free dynamic, if set in motion, is a lever acting on coevolutionary dynamics between Business and IS domains across all three levels.

In Table 4, we juxtapose five of the 1st Principles against nine scale-free theories. The latter are drawn (paraphrased) in Table 2 from Andriani and McKelvey (2006) and lined up with the Principle they support. Most, but not all, draw on some variant of positive feedback. In the following paragraphs, we discuss how managers can use the scale-free 'lever' to better enable the relevant Principle. We discuss them in the order that they would most logically be 'enabled' – that is, put into effect – in any organization so as to foster improved IS alignment.

1. Deviation amplification: We have emphasized the coevolution leading to IS alignment as a positive rather than negative feedback process – coevolution keeps the organizational levels appropriately connected to a moving target in the form of changing Business or IS external environments. Positive feedback, however, equates to Maruyama's (1963) 'deviation amplification'. This adaptive Principle is set in motion by the scale-free dynamics of *positive feedback* that can operate at all levels as a means of enabling the growth of initiating plans and events into significant IS alignment improvements from bottom to top.

We mentioned earlier that management commitment to IT, and its championing of important IT initiatives is a response to competitive environments and trying to achieve competitive advantage. Additionally, Business units and IS departments partnering to select and deploy an adaptive infrastructure and responding to users needs can all be considered as positive feedback coevolution. This positive feedback coevolution is also at the centre of Allen and Varga's article (this issue) on coevolutionary aspects of complexity theory applied to IS problems. Our intent in applying the *bottom-up* processes of self-organization and emergence – these elements of complex adaptive systems are discussed at greater length by Curşeu (this issue) and Merali (this issue) – is to push the idea that self-organizing agents can (at some probability) create significant new structures and processes apt to create better functioning IS. IS and other employees or managers do this by setting positive feedback 'development spirals' in motion in which the initial conceptions (insignificant instigation events) spiral into dramatic new structures as stakeholder groups attempt to see their views about system components embedded in the IS. Boehm (1988) argues that this approach:

1. Fosters the development of IS specifications that are not necessarily uniform, exhaustive or formal.
2. Incorporates IS prototyping as a risk reduction option at any stage of development.
3. Accommodates IS reworks or go-backs to earlier stages as more attractive alternatives are identified or as new risk issues need resolution.

2. Tension: IS alignment at any level is better enabled if managers bring tension to bear as a means of sparking coevolutionary dynamics. The tension Principle subdivides into two kinds of scale-free theories. First, the Prigogine kind – *tension* imposed on a system: as noted earlier management championing of IT initiatives to bring about state-of-the-art technology in organizations is management by tension. Adaptive tension at the gene, cell, organism, or species level speeds up coevolutionary adaptation in biology. We see the same thing happening in organizations where management commitment to IT is high and where IS staff and business units form partnerships because of management' imposition of tension. Second, the Kauffman (1993) kind – tension showing up as drives for improved fitness. He shows this to be true in biology at all levels – heterogeneous agents striving for improved fitness set off positive feedback spirals that generate *spontaneous order* in the form of fractal structures (see also Vidgen and Wang, this issue).

To go back to our earlier discussion of alignment failures, '*management by tension*' may be applied to Orlikowski's call for more improvization, Grant's bottom-up approach to business strategy, and working harder to define IS goals and keep them up to date with a changing environment. Both Business units and IS managers can more pointedly work to impose higher tension on managers to motivate them toward more experimentation, entrepreneurship, and initiative. *Management by tension* can apply to cutting costs, mending communications with business functions, keep up to date on IT, making it more user-friendly, and so on. Management by tension can be applied to everyone, everywhere, across all levels. It can be applied to IS functions, and Business strategy, operational and individual levels.

3. Requisite complexity: Organizations need to develop internal degrees of freedom in the form of IS and organizational abilities enabling a firm to respond to levels of external business and IS complexities that also may be changing. Firms do not want to pay for any more internal capabilities than they have to and do not want to learn about any more external degrees of freedom than is necessary. This leads to the *least-effort* scale-free theory. Least effort in language formation is as follows: (1) it does not pay for a listener to know more words than used by the person talking, and likewise, (2) the speaker does not want or need to know words that the listener cannot understand. The least-effort rule leads to efficient use of language words, as Zipf (1949) theorized and as recently confirmed by Ferrer i Cancho and Solé (2003). Least-effort applies to the Chinese language before it stabilized (Dahui *et al*., 2005), growing as opposed to stable firms (Ishikawa, 2005) and growth markets and transition economies (Dahui *et al*., 2006; Podobnik *et al*., 2006). Least effort also applies to firms wanting and needing to be efficient in matching up internal against external degrees of freedom – there is a cost to increasing internal degrees of freedom and a cost of reducing external degrees of freedom to the critically important ones. Boisot (this issue) concludes by noting that information abstraction and codification processes respond to Ashby's Law. We conclude that his abstraction and codification processes are essentially 'least-effort' searches for adaptive success.

The best way to think about least-effort dynamics in an IS context is in terms of the departments and users in our Figure 1. On the one hand, it does not make sense for IS people to talk to the Business people in terms of technical IT concepts (we could call it *IT-Chinese*) that the Business 'users' cannot understand or find relevant. Why would the latter spend their time and energy on learning this stuff? On the other hand, it does not make much 'energy-use' sense for IS people to keep putting time and effort into bringing state-of-the-art IT ideas and equipment (more *IT-Chinese*) into organizations filled with users who prefer the *status quo* and do not want to put energy into learning new ideas. In fact, what we see in all of the articles in this Special Issue is the opposite of least effort! Business and IS people both put huge amounts of time and energy and money into IS and IT concepts and hardware that are chronically misaligned. This entire issue is about the need for high effort, not least effort. There are two reasons why: (1) firms do not reach the least-effort state because they are unwilling, unable, or do not know how to put high-effort into play that is effective in working toward the least-effort end state; or (2) the pace of change in Business strategy and IT is such that no amount of high effort will ever reach the least-effort state – people are in fact trying, but in the changing IT world it will be a high-effort process indefinitely, with the least-effort '*Nirvana*' state out in the seemingly unobtainable future.

4. Near decomposability: Simon's near decomposability rule is brought to life at any level by three scale-free theories working together. First, we apply the *square-cube law* – what governs the simple cauliflower. The application of this law to firms dates back to Haire (1959). Nowadays, it is seen in terms of employees directly involved in bringing in resources to a firm – surface employees, as opposed to all the other employees that comprise the size of a firm – volume employees (Stephan, 1983). Carneiro (1987) applies the law to explain the upper bound on the size of villages. The law limits their size unless they develop what he terms 'structural complexity', where complexity grows at 2/3 power of a village's population. Only by doing this do villages avoid splitting into two.

Second, as soon as we have modules (subunits) we also have *connection costs*, another scale-free theory. Absent anarchy, as modules increase their number of inter-module connections, connection costs increase since these grow at a faster rate –depending on the number of other subunits. At some point, it is more efficient to recombine modules so as to lower communication costs. This balancing between the square-cube and connection costs laws gives rise to our third scale-free theory, *self-organized criticality* (Bak, 1996). Balancing may be achieved with numerous small – or a few large – adjustments in near decomposability – adjustments between more or fewer modules and more or fewer communication links. Managers, thus, manage at the critical edge of staying at the most efficient amount of modularity and inter-module connections.

In managing IS alignment, the general rule here is that too much subunit autonomy leads to misalignment because the parts are unaware of each other. In other words, if each of our levels (strategic, operational and individual) with its two poles of duality (IS and Business) has full authority/autonomy to make decisions, without being required to coordinate or seek approval from the other level or pole, misalignment will occur. But, if the parts become too large they cannot align simply because they become like elephants – too big and slow to quickly respond to changing conditions at any of our three levels. The parts of many early IS were so tightly coupled that it was impossible to continually evolve in a changing IT world. Hence, when a major change was required the system had to be discarded. Modular design has been proposed as a useful means to manage IS complexity (Homann *et al*., 2004). Modular and agile IS can only be achieved through a modular architecture that allows components to be removed, replaced and reconfigured in a more dynamic fashion than current tightly coupled designs allow.

From the coevolutionary point of view, modular design can be understood from the viewpoint that large, complex socio-technical systems, such as IS, consist of coevolving, interacting subsystems that exist in some environment, where perturbations to one subsystem or to the environment create the possibility for evolution elsewhere in the system – as shown in Figure 1. Modular design is, thus, the series of big or small coevolutionary moves that IS managers make, or could make, over time to work toward the most optimally sized IS units (Business function managers should be doing the same thing). Useful moves may be unanticipated *a priori*, or have unexpected and unintended user consequences. These moves may range from very many *frequent-but-small* subunit re-sizings that are continually adjusted to strategic and IT change dynamics that are more *dramatic-but-infrequent* total re-organizations. IS subunits that are too small increase connection costs or fail in connective response, but IS units that are too large become unwieldy and unresponsive monoliths.

5. Rate of genetic variance: Efficacious adaptation is enhanced by the *rate* of internal change. Firms, as well, are limited if they cannot change their capabilities; thus, new learning is limited by a firm's absorptive capacity – the knowledge employees already have about various topics limits their ability to learn new things (Cohen and Levinthal, 1990). Needless to say, the more heterogeneous are a firm's employees (heterogeneous agents), the quicker a firm can learn new things. For a study of the interaction of heterogeneous agent connections *vs* strong culture and performance, see Canessa and Riolo (this issue).

First, we emphasize *preferential attachment*. As firms or subunits grow, they need and attract more incoming employees – it is a case of the rich getting richer, or in this case, 'success breeds success', or what Arthur (1990) calls 'increasing returns to scale'. Experienced IT professionals with broad technical competency and working knowledge of management are attracted by firms where IT is considered key to competitive advantage. This, however, relies on a stream of entering employees, which is the key part of the preferential attachment law – it only fosters learning improvements if the incoming employees are heterogeneous in what they know. Then, as the new arrivals become attached to growing subunits they become sources of new learning for existing employees.

Second, we have the *1/4 power law*. This is a knowledge flow rule: the success of the square-cube law in governing the development of plants and animals in biology is also a function of the flow rate of energy from surface areas where it is collected to volume areas controlling the size and movement of the organism. We have already discussed how the square-cube law relates to Simon's near decomposability rule. But, as one can imagine, in any firm the viability of any business or IS subunit depends on resource availabilities, whether cash or learning. In short, the effectiveness of any modular design is not only a function of module size and inter-module communication but also of resource flows at the several levels we discuss. All these elements enhance the rate at which organizations respond to new issues that surface and necessitate identification, interpretation, articulation and resolution in real time. Some time ago, Stalk and Hout (1990) focused on what they called 'activity loops' to speed up the reaction to unplanned events:

1. *Observation* (seeing situation and adversary).
2. *Orientation* (sizing up vulnerabilities and opportunities).
3. *Decision* (deciding which combat manoeuvre to take).
4. *Action* (executing the manoeuvre).

These loops should not only be executed rapidly, but they should also be flexible and responsive to requisite changes triggered by the environment. This loop process also applies to IS/Business coevolutionary looping dynamics since it is characterized by the emergence of new issues that surface very quickly during the process. This process necessitates effective users to identify changes required in the system and designers able to initiate and implement the changes required through a continuous, rapid, interaction process (Boland, 1978; Davis, 1982).

Conclusion

Despite years of cumulative research in IS alignment, it remains one of the most elusive and leading areas of concern for business executives. Indeed, achieving and sustaining alignment over time is complex not only because of its multi-faceted and coevolutionary nature but also because of the complex mutual influences between IS and various organizational domains that maybe operating simultaneously over time.

Instead of focusing upon simple cause–effect deterministic logic, our analysis uncovers a chain of causal dynamics. We summarize it with five propositions:

1. Organizational effectiveness is a function of IS alignment.
2. IS alignment is a function of coevolutionary dynamics spreading across three levels, individual users, business and IS subcomponents, and top-level business strategy.

3. Coevolution is a function of McKelvey's (2004) seven 1st Principles.
4. The 1st Principles are a function of nine scale-free dynamics.
5. IS alignment leadership begins when managers enable scale-free dynamics.

These propositions exhibit an inescapable logical flow going from managerial action to impact on the outcome variable of organizational effectiveness. Furthermore, (1) either the coevolutionary and scale-free dynamics are already in place, or (2) one or more of the causal stages need to be set in motion. It is also possible that the dynamics are in place but working counter productively so as to actually *increase* IS misalignment – there is nothing to say that, willy-nilly, these dynamics are strategically correct. From a managerial action perspective, enabling all dynamics more or less in parallel is best; but the following sequence is workable: (1) inducing tension; (2) setting the creation of requisite complexity in motion; (3) managing the interaction between modularization and connection cost efficiency; (4) speeding up the change rate of knowledge acquisition and interaction; and (5) fostering deviation amplification.

Anyone can instigate these dynamics because of their scale-free nature – at the top strategy level, at the bottom individual users level, or among the Business and IS subcomponents in between. Welch managing at GE is a good example of managing complexity dynamics at the top (Mackey *et al*., 2006). The emergence of genetically altered bio-products at Monsanto is a good example of middle level emergence of a product that ballooned to take over the firm (Day and Colwell, 2006). The enabling of bottom-up emergence of the processor chip at Intel demonstrates the presence of these dynamics at the bottom (Burgelman, 2002). Admittedly, these examples are not specifically relevant to fixing IS misalignment, *per se*, but they illustrate real-world managerial actions at the different levels we discuss. Arguably, for IS alignment it is better to have these dynamics initiated by IS managers. All of the non-IS managers typically have their hands full with other coevolutionary dynamics that may or may not be functioning very well. IS managers can help, and demonstrate that they *can* help by taking '*complexity leadership*' on this.

Space limitations preclude us taking on the topic of complexity leadership. Current leadership theories are still stuck in the clanking machine age. Further, they start with the (top) manager's vision and charisma and then talk of these cascading down organizational levels (Waldman and Yammarino, 1999). The complexity leadership alternative is developed by McKelvey (2001, 2006) and Uhl-Bien *et al*. (2006). The latter develop a leadership perspective that moves beyond bureaucratic assumptions and views leadership as a process – *a complex interactive dynamic through which adaptive outcomes emerge*. Their adaptive leadership perspective recognizes that leadership is too complex to be described as the act of an individual or individuals; rather, it is a complex interplay of many interacting forces. They identify a set of these forces to illustrate how they relate to adaptive leadership, the role of adaptive leaders, and their enabling role. They argue that leaders can manipulate conditions that set these forces in motion, as we suggest in our five propositions. The Mackey *et al*. (2006) description of the 12 simple rules that Welch put into practice as CEO of GE offers one example of complexity leadership in action. These rules stem from the basic complexity theories generated by the European and American schools of complexity science we mention earlier.

Notes

1 We use the term Business ('B') capitalized, to refer to all aspects or elements of corporate strategy, or subunit strategies that are individually important or that are part of an overall corporate strategy, to which IS strategy needs to be developed with respect to.

2 The notion of fit here refers to the degree to which the IS mission, objectives and plans support and are supported by the business mission, objectives, and plans.

3 IS structure has been defined as the locus of responsibility, the total set of centralized/decentralized solutions for the management of IS (e.g., computer operations, networking, and emerging technologies), and the management of the use of IS (Brown and Magill, 1994). In other words, IS 'structure' refers to the formal rules that are readily observable through written documents or rules that are determined and executed through formal position. Formal structure, thus, includes dimensions such as formalization (amount of written documentation), specialization (degree to which tasks are subdivided), standardization (extent to which work activities are performed in a uniform manner), hierarchy of authority (who reports to whom and the span of control of each manager), complexity (the number of activities and subsystems within the organization), centralization (the hierarchical level that has authority to make a decision), etc.

4 We attend to two aspects of organizational components, structural and social. The first refers to the formal dimension of alignment. The second investigates the actors in organizations, examining their values, communications with each other, and ultimately their understanding of each other's domains (Dougherty, 1992). This component has been referred to as social or cultural dimension (Reich and Benbasat, 2000). We further refer to both dimensions as operational including both the formal and the informal aspect.

5 Eldredge and Gould (1972) coined the term, *punctuated equilibrium*,in 1972. It describes a view of evolution not as continual gradual change but of long periods of near stability intermittently disturbed by short bursts of new species creation. The two paleontologists found that evolution happens, not as a continuous steady process, but as a response to changed environments that isolate of small populations away from the main gene pool of a species.

6 The punctuated equilibrium model was created to explain the discrepancy between Darwin's notion of 'gradualism" (very slow evolutionary change) *vs* what appears in geology as gaps in the fossil record. In this respect it is a *descriptive* theory. We disagree with Orlikowski's critique that it necessarily favors stability – this sets it up as a *normative* theory – which it isn't. It recognizes that both very slow and very rapid changes can occur.

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