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Explaining information systems change: a punctuated socio-technical change model

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Abstract

We outline a *Punctuated Socio-Technical Information System Change model*. The model recognizes both incremental and punctuated socio-technical change in the context of information systems at multiple levels – the work system level, the building system level, and the organizational environment. It uses socio-technical event sequences and their properties to explain how a change outcome emerged. The critical events in these sequences correspond to gaps in socio-technical systems. By conceiving information system (IS) change as a multi-level and punctuated sequence of socio-technical events, IS researchers can conceive plausible and accurate process explanations of IS change outcomes, including IS failures. Such explanations are located in the middle range and thus avoid the highly abstract and stylized closed-boxed factor models of change, but go beyond the idiographic open box histories of singular change processes.

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Introduction

Information system (IS) change is concerned with generating a deliberate change to an organization's technical and organizational subsystems that deal with information (Swanson, 1994). Describing and explaining the content, scope, drivers, and dynamics of this change has remained contested and challenging. A majority of change studies treat the change as a simple, linear progression where a new (technical) system is designed, adopted, and modified in step-wise manner (Lyytinen, 1987a; Lyytinen *et al.*, 1998). In their simplest form, change explanations use variance theories, which correlate static vector measures about the system and its environment before and after the change (Mohr, 1982). These explanations close-box the change process and mask its dynamics and generative mechanisms. When the change is seen as a process and gets white-boxed – for example as in planned models of change (Keen & Scott-Morton, 1978) – such inquiries still separate technical and social change, and view both in a cumulative fashion. They therefore miss the drama that characterizes most IS change processes, which Drummond (1996a) referred to vividly as 'Mad Hatter's Parties' and where a success turns into a failure overnight. When richer socio-theoretical or socio-technical frameworks like structuration theory (Orlikowski & Robey, 1991; DeSanctis & Poole, 1994) or social shaping of technologies (Walsham & Sahay, 1999; Howcroft *et al.*, 2004) have been adopted to account for the change, these accounts rarely view it in non-linear terms. They do not draw on explicit process theories in

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explaining the change. This is not surprising as the main interest of these frameworks lies elsewhere: how to account for the recursive dependency between technologies and social structures (Orlikowski & Robey, 1991), or how meanings attached to technologies stabilize (Howcroft *et al.*, 2004). Being grand theories of social change and structure they were never meant to be a guide in building rich, generalizable and localized socio-technical explanations of IS change.

The challenge faced by IS scholars is the following: how can they explain such a complex change with reasonable accuracy and generalizability, but, yet, render these explanations simple enough? The goal of this study is to propose one approach to theorize about the IS change that meets these goals. In short, we engage in the process of theorizing (Weick, 1989, 1995b) and our desire is to inch towards better explanations of why and how IS change takes place. To this end we approach IS change as complex, socio-technical episodic change, and formulate a theoretical vocabulary in which IS change can be recorded, described, and explained. Overall, we aim to make some modest steps to build better explanatory frameworks that can offer *middle-range explanations* of the IS change. We suggest that they will go some way to overcome the limitations of too general, or too accurate explanations of IS change in the past.

The proposed model, called a Punctuated Socio-technical IS Change (*PSIC*) model is laid out as a sensitizing device to explain complex IS changes. The proposed model addresses three questions related to IS change: (1) what is the scope of IS change and how should we describe its organization and the properties of systems that are involved in IS change (Lyytinen, 2004), (2) what is the nature of the change in systems associated with IS change (Gersick, 1991; Greenwood & Hinings, 1996), and (3) what is the content and 'engine' of these changes as a socio-technical phenomenon (Leavitt, 1964; Lyytinen *et al.*, 1996, 1998)? To address these questions we integrate three theoretical streams into a theoretical model of IS change: (1) theories of multi-level systems and punctuated equilibrium, or episodic system change, (2) socio-technical system theory, and (3) process theorizing. First, the proposed model draws upon *episodic system change theories* (Gersick, 1991; Greenwood & Hinings, 1996; Plowman *et al.*, 2007) and systems theory (Lyytinen, 1987b; Lyytinen *et al.*, 1996; Alter, 2002), an approach which sees IS change as a multi-level, non-linear process. Second, it draws upon *socio-technical (S-T) system theory* (Leavitt, 1964; Lyytinen *et al.*, 1996, 1998) as to identify the *engine and content of IS change*. Finally, the model draws upon *process theories* (Mohr, 1982; Langley, 1999; Pentland, 1999; van de Ven *et al.*, 1999) to formulate the 'theory' of IS change as a plausible explanation of IS change.

The remainder of the paper is organized as follows. The next two sections discuss the theoretical assumptions of IS change as a multi-level, punctuated change. In a further section, we characterize assumptions concerning the 'engine' and content of the IS change by drawing upon S-T theory and then we operationalize theoretical premises into the PSIC model by showing how IS scholars can build visual process models, which identify and explain IS changes as a multi-level, punctuated socio-technical change. Later, we illustrate the use of the PSIC model in explaining IS change by comparing it with Newman & Robey's (1992) well-known process model in explaining the implementation of a large underwriting system in an insurance company called Hartfield over a decade. Then we evaluate the proposed model comparing it with other IS change explanations and in the same section we emphasize the need for middle-range 'open box' approaches that come with alternative ontological and epistemological underpinnings. Finally, the paper ends with a summary and our concluding statements.

Premise 1: IS change in research

The *change* of *information systems* covers the generation, implementation, and adoption of new elements in an organization's social and technical subsystems that store, transfer, manipulate, process, and utilize information. (*Note*: To help to follow our theory building we provide definitions for key terms in italics in the Appendix). In general, this change has been characterized as uncertain, ambiguous and hard (Lyytinen *et al.*, 1998; Bergman *et al.*, 2002a, b). First, developers face uncertainty in predicting the impact of their interventions due to complex interactions between the elements in the design and change context. Second, IS change is ambiguous in that the nature and means of IS change vary over time while its context changes, or when designer's cognition fails (March & Olsen, 1976; Baier & March, 1986). Finally, IS change is hard due to the scale and scope of effort necessary to mount the change. Accordingly, such change processes can exhibit amazing longevity and resilience: they can grow from modest project plans into uncontrollable behemoths that are condemned to wander never reaching the 'promised land' of change (Lyytinen & Hirschheim, 1987; Keil, 1995; Drummond, 1996a, b). Without making a claim that the following analysis is complete, or the proposed classification the only suitable one (such a review is beyond the scope of this essay) we next distinguish four streams of IS research that have sought account for IS change: (1) descriptive, causal models of IS change, (2) normative IS development process models, (3) studies of IS adaptation, and (4) studies of IS failure.

Descriptive, causal or feedback-based models of IS change describe or explain how start and end states of the IS change interrelate. They seek to predict how the scale, complexity, uncertainty, or change rates affect the success or the rate of IS change. Causal models of IS change view it as a simple mapping from a vector of start states – for example change uncertainty – to a vector of end states (e.g. delays or cost overruns), and show that these two sets of states correlate strongly. Similar factor models have been adopted in the organizational impact literature to explain organizational outcomes of IS change such as organizational efficiency (Markus & Robey, 1983). These factor models close-box the process of change and its organizational environment and treat both as variable values. Recently, some descriptive models of IS change have also integrated process states variables in explaining the change outcomes (Robey & Newman, 1996). Feedback based models of IS change have used feedback based causal system models and simulations to dynamically analyze change trajectories. For example, Abdel-Hamid & Madnick (1989, 1990, 1991) simulated software development behaviors using system dynamics and showed path dependency and non-linear change in software project performance.

Normative IS development process models focus on how IS change *can be* produced by defining guidelines and routines for enacting the change (Hirschheim *et al.*, 1995). They suggest how IS development activities can be defined and organized for identifying and executing the change (Truex *et al.*, 2000; Bergman *et al.*, 2002a, b). Typically they seek to address the concerns of uncertainty, complexity, and scale in IS change. They assume, however, that the IS-deploying organization will respond to the identified technical change benignly if the change is adequately specified, professionally designed, and soundly implemented based on a method (Truex *et al.*, 2000; Madsen *et al.*, 2006). The 'hard' part is to identify the right change, that is, get the requirements right and describe them in ways which allows to control for the change. When followed, the 'right' change will take place in a disciplined fashion incrementally. Therefore, the IS development change is orchestrated as a linear progression towards a faithful compliance with the system requirements by shifting normatively design activities from organizational requirements (organizational design options) to technical design (technical design options), and then implementing it into the organizational routine (Parnas & Clements, 1986; Lyytinen, 1987a; Truex *et al.*, 2000). The literature disagrees primarily in how one should sequence these tasks: whether the waterfall model or an evolutionary sequence will do the job (Parnas & Clements, 1986; Lyytinen, 1987a). The organizational implementation literature complements this by suggesting how to effect the planned change by moving the organization in a direction that meets the requirements (Kwon & Zmud, 1987).

In both the descriptive and normative analyses, the IS change is mainly located at one level whereas changes in other levels – organizational environment, current system use – remain in the background and close-boxed. They assume also that design activities will produce the change smoothly, and the design system remains stable (Lyytinen *et al.*, 1998). Moreover, the IS change involves one dimension only – it is either social or technical – and its nature is linear and cumulative.

Studies of IS adaptation characterize the dynamics of the system use and its change (Orlikowski, 1996; Orlikowski & Hofman, 1997). They focus on the uncertainty and ambiguity associated with the change by connecting it with socio-technical (Mumford, 2003), political (Keen, 1981; Grover *et al.*, 1988), and strategic shifts within the organization and its environment (Scott-Morton, 1991). Most such changes are observed *after* the change in the technical sub-system has been carried out and change in the technical system remains largely 'close-boxed' in these accounts. Studies of system adaptation are typically longitudinal and ethnographic, with the exception of Black *et al.* (2004) which used simulation. They portray a rugged landscape of change, one very different from the normative or descriptive accounts of IS change. IS change is seen both as incremental adaptation and leap-frogging which involves 'lumpy' transformations (Tyre & Orlikowski, 1994; Lassila & Brancheau, 1999; Majchrzak *et al.*, 2000; Black *et al.*, 2004). Such views are compliant with the idea of emergence and episodic change (Tushman & Romanelli, 1985; Romanelli & Tushman, 1994; Fox-Wolfgram *et al.*, 1998; Weick, 1998; Halinen *et al.*, 1999). In such view of change small incremental adaptations in IS are generated by contextual variation (Weick, 1998). Yet, this does not exclude but also promotes abrupt, *gestalt* changes. These happen when the change in the system reaches a critical specification and ignites a pervasive and deep change in the IS environment (Tyre & Orlikowski, 1994; Plowman *et al.*, 2007). Such shifts can result from discrepant events or misalignments between system elements or differences in the way in which different elements in the social system interact (Lassila & Brancheau, 1999; Majchrzak *et al.*, 2000; Black *et al.*, 2004). Overall, IS adaptation studies renounce the idea that IS change is solely about steady improvement. In contrast, many changes are not judged as improvements while others are emergent and unintended (Lassila & Brancheau, 1999).

Studies of system failure explore why the planned changes were not realized and why the change process failed to deliver the system (Lyytinen & Hirschheim, 1987; Davis *et al.*, 1992; Markus & Keil, 1994; Keil, 1995; Drummond, 1996a, b). Thus they focus on the ambiguity, uncertainty, and scale associated with IS change. Perhaps, because of the extreme nature of the identified outcomes, these studies view IS failures as *abrupt* changes in the projected and expected IS change trajectory. Accordingly, they seek to account for IS failures as unintended, undesirable, and non-linear IS changes by carrying out detailed process or factor analyses (Newman & Robey, 1992; Markus & Keil, 1994; Keil, 1995; Drummond, 1996a, b; Newman & Sabherwal, 1996), Typically these studies attribute IS failures to the features of the technical system (Lyytinen & Hirschheim, 1987), features in the process dynamics (Newman & Robey, 1992; Newman & Sabherwal. 1996), features of the designers and participants (Keil, 1995), or features in the environment and decision-making (Drummond, 1996a). The weakness of such accounts has been the lack of recognizing IS failure as an example of a more general transformative nature of

IS change, and ignoring interactions between design and use and the organizational environment in producing the IS change (see however Lyytinen *et al.*, 1996, 1998). In addition, their view of IS change has remained one-sidedly negative in that they study exclusively failures, and thus negative, non-linear change.

In summary, past studies build primarily 'horizontal' descriptive or prescriptive process explanations of IS change. In this context they suggest rich vocabularies to describe and understand the complexity and uncertainty associated with IS change. As they mostly focus on one level of change they tend to forego interactions with multiple systems and the organizational environment. They also tend to separate and focus either on technical or social change, and view both changes in linear terms. In addition, ethnographic studies of system adaptation and use, and design practices, and longitudinal accounts of failed systems, recognize abrupt change at one level. Overall, these accounts combined offer a good starting point to construct a framework to explain IS change, but IS change as complex, multi-level, episodic change where simultaneous processes interact creating unpredictable and dynamic change outcomes.

Premise 2: IS change as multi-level, punctuated change

We will next address the question: what is the scope of IS change? To this end we will characterize IS change as multi-level and episodic change by drawing upon theories of systems (Lyytinen, 1987b; Lyytinen *et al.*, 1996; Alter, 2002), and episodic change (Gersick, 1991; Greenwood & Hinings, 1996; Plowman *et al.*, 2007). These theories provide an initial vocabulary to narrate *IS Change* as a process, which creates and/or re-configures *elements* and their *relationships* within and between three realms: (1) signs and symbols; (2) organizational tasks, structures and processes, and (3) an organization's technological core (Lyytinen, 1987b). We will next identify: (1) the essential levels that define the scope of IS change, and (2) how these levels change. Related issues like who determines what the issues are during change (stakeholder analysis); or what or who determines the change issues (espoused theories of IS change) will not be discussed as they are beyond the scope of this study.

IS change is multi-level

IS change re-configures a *work system* by embedding into it new information technology (IT) components. Such work systems execute, coordinate, and manage information-related work (Alter, 2002; Bergman *et al.*, 2002a, b; Mumford, 2003). They are characterized by low malleability due to path dependencies, habitualization, cognitive inertia, and high complexity. Because of this rigidity and complexity, IS change must be planned and deliberate (Lyytinen, 1987b; Alter, 2002). Therefore, an analytically separate system called the *building system* (Lyytinen *et al.*, 1996) needs to be erected. This building system commands a set of resources and enacts routines to carry out the change and address the issues of uncertainty, ambiguity, and complexity. To do so it needs wield power to overcome resistance, to obtain resources, and to legitimize the change (Markus, 1983). The building system is in most cases separated in space and time from the work system as the building system precedes it in time (Orlikowski, 1992). Analytically, the work system can thus be located before the building system, although in actual change analysis they need to be viewed as co-evolving. In fact, their constant interactions create multi-layered, staggered, and cascading changes across both systems.

The building system and the work system are always embedded in a broader system, which we call the *organizational environment*. The recognition of the environment brings to the foreground several pivotal factors that influence the direction of the IS change at both system levels. Following Pettigrew (1990) we divide this environment into two parts: *the organizational context* (the inner context) and the *environmental context* (the outer context). We define an organizational context as the immediate organizational environment of the building system that includes the resource, authority, culture, and political systems in which the IS change unfolds (Pettigrew, 1990). The environmental context, in turn, includes an organization's social, economic, political, regulatory, and competitive environments that influence and are influenced by all other system levels.

Viewing IS change as multi-level change invites us to apply two intellectual strategies in accounting for the change: *vertical* and *horizontal*. The vertical analysis unpacks interdependencies between three levels – work system, the building system, and the environment – while accounting for the IS change. The horizontal analysis, in turn, focuses on horizontal and temporal interactions at two 'lower' levels of IS change to reveal, for example, path dependencies in the building system and the work system. Accordingly, three separate streams of analysis can be distinguished. (1) An analysis of the changes in the IS change content – what was done by the building system to generate the IS change. This analysis is carried out diachronically by investigating the flow of activities/events within the building system. (2) An analysis of the actual intended or unintended changes in the work system – what actually happened in the work system and what did truly change. This horizontal analysis is carried out by analyzing how work system interacts with the building system and how it transforms itself over time due to these or other interactions. (3) A diachronic analysis of interactions between the work system, the building system, and the environment. These vertical and temporal (horizontal) analyses delineate the dynamic influences of the environment on the building system, and/or work system and their mutual dependencies. As will be shown, the PSIC model integrates all these three streams of analysis while we build process explanations of IS change.

IS change is punctuated

We will next analyze the question: what is the nature of the IS change? Theories of (system) change distinguish between two paradigms concerning the nature of change (Tushman & Romanelli, 1985; Gersick, 1991): one of continuous, incremental change where a change accrues from a slow stream of small mutations; and another of revolutionary, episodic punctuations where compact periods of metamorphic change (revolution) are followed by periods of stability and slow and small mutations (equilibrium). Accordingly the change is either convergent or radical in scope, and evolutionary or revolutionary in pace (Greenwood & Hinings, 1996). The first paradigm – incremental change – where change is convergent and evolutionary is rooted in the idea of Darwinian mutations: change is continuous, incremental and cumulative. Even pervasive change like the creation of a new species takes place through small additive steps (Gersick, 1991). In the second paradigm, that of episodic change, the change is radical and revolutionary – though it is sometimes incremental and slow, in other situations it will be rapid and abrupt. Accordingly, change is not always progressive, because systems are seldom malleable in all dimensions to permit incremental change to scale over time (Gersick, 1991).

In this paper we posit that IS change is not solely or even mainly incremental and cumulative, but it primarily, episodic. Such a view of IS change is also recognized in both IS failure studies and studies of IS adaptation. Such episodic changes we call *punctuated* after Gersick (1991) and this explains the term punctuated change model. Philosophically this view dates back to Hegel's dialectics, which recognized already that systems evolve through stages, which follow alternative behavioral laws (Hegel, 1969). The same idea was also prevalent in Marx's theory of dialectics. In line with this, change at any of the three levels during IS can be viewed as alternations between longer periods of incremental adaptation – called first-order change – and briefer periods of revolutionary, episodic upheaval – called second-order change (Gersick, 1991; Fox-Wolfgram *et al.*, 1998). This also applies to the ways the work and building systems interact – some interactions result in incremental adaptations, while others result in punctuations in either, or both of them. To apply this paradigm of change to explain IS change we will recognize four characteristics of punctuated change: (1) change is not always smooth and gradual; (2) the systems will reject change – small or large – under certain conditions; (3) the systems do not possess teleology; and (4) the system's composition and interaction principles alter fundamentally during punctuations. If we apply these four characteristics to all levels of IS change we can note the following (Gersick, 1991; Fox-Wolfgramm *et al.*, 1998):

(1) Systems associated with IS change possess *a deep structure*, which refers to the set of fundamental 'choices' a system has made of 'i) the basic parts into which its units will be organized, and ii) the activity patterns and principles of interaction that will maintain its existence' (Gersick, 1991, p. 14). In 'choices' we assume no agency or teleology as the choices can be outcomes of blind adaptation. These deep structures remain stable in that they are inherited from history and manifest path dependency (Garud & Karnoe, 2001). Moreover, the activity patterns enabled by the deep structure reinforce the current structure and behavior through positive feedback (Gersick, 1991). Therefore, initial conditions and first moves in the system's adaptation are often the most important and fateful (Plowman *et al.*, 2007).

(2) Systems associated with IS change go through periods of *stability*, which are dependent on and determined by the system's deep structure. Although Gersick (1991) uses the term equilibrium, we prefer to use the word stability as between punctuations the system drifts and changes and it is not at all times in *total* equilibrium. As Gersick (1991, p. 16) argues, periods of stability 'consist of maintaining and carrying out these choices' made about the deep structure. Periods of stability are sustained by inertia due to routinization, cognition, motivation and obligation, and the benefits of a stable environment (Tushman & Romanelli, 1985). During stable periods, systems undergo limited adaptations by responding to environmental perturbations. Such changes can be fast paced due to the nature of the internal change, and the swiftness of external perturbations. Yet, all these adaptations keep the deep structure intact.

(3) Systems associated with IS change face occasionally episodes of *system upheaval*. Although Gersick uses here the term revolutionary, there is often nothing 'revolutionary' in these punctuations. In fact, her own study of differences in team behaviors at distinct stages of the project for example carries no connotation of a deliberately planned revolution (Gersick, 1988). These episodes are characterized by the need to reform the deep structure. If the upheaval is successful the existing deep structure is dismantled, and a new deep structure crystallizes into an alternative reified configuration. The configuration consists of both old elements and pivotal new pieces. Yet, they operate under a new and different set of rules (Gersick, 1991). The upheavals originate either from an internal trigger – a misalignment between critical system elements – or from novel, unexpected external changes so that the system cannot adjust to its environment. The upheaval may also fail and the system falls back to its old deep structure. Sometimes the system can escalate into continued disarray where it oscillates between upheavals and attempts to bring order.

(4) Punctuated IS change embraces a *multi-level explanation of change*. This requires us to observe differences between incremental change and deep structure

> transformations. Incremental, horizontal explanations are useful only in explaining first-order change. In contrast, punctuated change is embedded in and affected by multiple levels that operate under different temporal orders. To analyze second-order change requires that the investigator explores changes at multiple levels and seeks to understand their interactions. He or she must also distinguish between incremental and deep changes at each level. Therefore, change accounts cannot be reduced to solely horizontal explanations but they must recognize qualitative change and emergence (Truex *et al.*, 2000; Madsen *et al.*, 2006).

Punctuated change theory suggests that change at any level can sow the seeds of a punctuated IS change: it can re-configure the deep structures of work systems, re-orient or revamp building systems, or lead to radical reorientations towards, and within the environment. Punctuations add novel technical elements, replace, remove or expand organizational structures and routines, and wipe out ideas, beliefs, skills, and values that underpin and are embodied in the organization (Greenwood & Hinings, 1996). Punctuated change also observes that IS change can be extremely difficult to achieve due to routinization, cognitive inertia, motivation gaps, and obligations (Tushman & Romanelli, 1985; Gersick, 1991). Such stability is also preferred due to managerial choice (Scott-Morton, 1991), actors' interests (Latour, 1987), career planning, cognitive framing, pressure from the organizational environment (Lawrence & Lorsch, 1967), or infrastructural investments and routinization. An upheaval can emerge as a response to an internal change in the work system such as learning failures, or from the external pressure exercised by institutions (DiMaggio & Powell, 1983), or the competitive environment (Scott-Morton, 1991). Overall, IS change in this paradigm of change emerges as a continuous oscillation between periods of incremental adaptation – referred to here as stability and exemplified in terms like IS 'maintenance' or 'normal project operation' – and moments of system upheaval as exemplified by terms like 'radical system change' or project 'termination' (Lyytinen & Hirschheim, 1987; Markus & Keil, 1994).

Premise 3: IS change as socio-technical change

We will next address the question: what is the content and engine of IS change? In particular, we suggest that IS change can be viewed simultaneously as technical and social change and why punctuated IS change involves both and intertwines them.

IS change and socio-technical change

When we approach IS change as punctuated involving all three levels, we must ask: what are the 'menus of choice' (Gersick, 1991) associated with the structure and composition at each level? This menu of choices should offer a simple, comprehensive, and flexible vocabulary to characterize elements and their connections that change, and to describe changes both in the deep structure (punctuation) and during incremental variation. It should offer also a means to detect the origins of both types of changes and provide a description of how system levels interact. Finally, for theoretical elegance it should offer a way to describe uniformly punctuated change at different levels. For these reasons, we adopt *S-T theory* to characterize the content and engine of IS change (Leavitt, 1964; Kwon & Zmud, 1987; Lyytinen *et al.*, 1998). To wit, the S-T components and their connections can be regarded as the general 'lexicon' for describing generative mechanisms and outcomes associated with the IS change.

Originally, Leavitt's S-T model synthesized the main contours of theories of organizational change 'as a kind of sharp caricature of underlying beliefs and prejudices about important dimensions of organizations' (Leavitt, 1964, p. 55). The model views organizational systems as multivariate systems of four interacting and aligned components – *task, structure, actor*, and *technology*. We leave here aside how the borders between these categories are determined, and how things that change are sorted out. As Bloomfield & Vurdubakis (1994) note, boundary disputes – especially between technology, structure and actors – are socially constructed and not ontologically fixed. In *real change situations* such borders will be drawn through political struggle that defines the legitimate range of socio-technical interventions. The way in which these disputes are resolved is, however, beyond the scope of this paper. These four components build up the technological, the social, the organizational, and the strategic cores of the organization (Scott-Morton, 1991). Figure 1 clarifies the content of those components and their connections at the level of a building system. For brevity, we refrain from representing similar models for work systems and the organizational environment here.

Leavitt's model displays the virtues of a good classification: it is simple, extensive, sufficiently well defined, and anchored in the extant theory. It can be, if needed, easily extended with other categories to obtain richer vocabulary, but for the sake of simplicity we will not do so in this essay. For example, Kwon & Zmud (1987) augmented

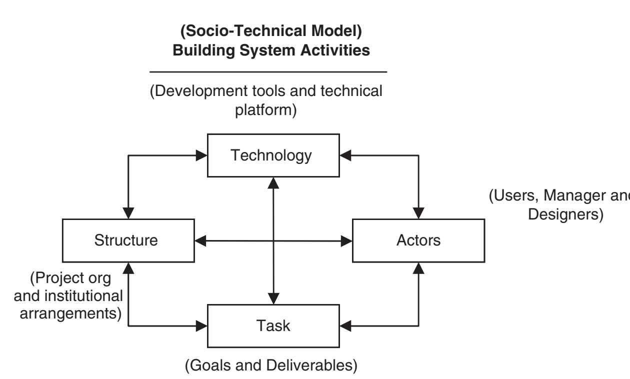

Figure 1 Socio-technical model of a building system.

their model with the concept of an environment, and other studies have included also culture (Davis *et al.*, 1992), or dimensions of systems of meaning (Giddens, 1984).

Following our multi-level approach we also assume that each component can be recursively decomposed into subcomponents, which allows for description of the content of change at two first levels of IS change (Mumford, 1983, 2003; Lyytinen *et al.*, 1996, 1998; Alter, 2002, 2005), and also the organizational environment (Scott-Morton, 1991; Yetton, 1997). The S-T model also recognizes external interactions through its notion of open environment. The definition of each S-T component within the S-T model as seen at each system level, their main properties, and representative literature in the organization theory and the IS literature are listed in Table 1.

Socio-technical systems during IS change are open. Owing to openness, systems need to continuously adapt to their environment to maintain the *system state* stable, where the four elements are mutually aligned. *System stability* involves stable relationships within and between the system components and its environment. In such a state the system can respond adequately in relation to its task, and its performance does not deteriorate. This concept of system equilibrium implies the corollary of *system instability*, where the four components are not aligned and system responses are less predictable in relation to its task, and its performance can deteriorate. By distinguishing these two states we distinguish dynamically system trajectories where systems move over time between stable and unstable states generating various *patterns of change*.

IS change as punctuated socio-technical change

Traditionally, socio-technical thinking has assumed that the systems will remain stable due to low component variation and their strong mutual interdependencies. Occasionally, when any one component becomes incompatible with others due to increased variation (e.g. malfunctioning, learning, replacement) we can observe a structural misalignment, which we label here a *gap* – a property of a system that affects the systems' behavior and its repertoire of responses. A gap is any contingency in the system which, if left unattended, will reduce the system's performance and threaten its viability. Often *events* that generate gaps are abrupt: a system failing, a financial crisis, or key people leaving. In other situations the system can drift towards the misalignment: a gradual and innocent change in one component reaches a tipping point that pushes the whole system into a misalignment (Plowman *et al.*, 2007). For example, a gradual and small increase in the system's input volume can break the technology and affect the whole work system. We call any event that generates a gap a *critical incident*. We follow here Flanagan (1954) who proposed a technique called critical incident technique to observe situations where one observes human's responses to explicit situations and seeks to discover reasons for (not) achieving intended outcomes. We extend his idea here to analyzing changes in responses from a building system/organizational/work system to problematic situations (misalignment) in its operation, or in relation to other system's operations. Overall, critical incidents form the necessary conditions for a system state to change: this change would not have happened without the event. An example of a necessary critical incident would be introduction of a new development tool within the building system that is resisted and not used. Its effective use would demand, however, a sufficient radical change in the organization and people, which is not carried out. Thus the other components do not adjust and the change does not have any effect on the systems. Any change in any component can, however, become a critical incident in some environments. Critical incidents are thus seen in our analysis as events that affect system states in ways which can threaten or significantly decrease or change its performance. The concept of critical incident is illustrated in Figure 2.

To maintain equilibrium in the socio-technical system one typically organize it in ways that helps control it and mitigate variations in its components (Mumford, 1983, 2003). At the same time, IS change *increases variation* in multiple, nested socio-technical systems. Table 1 shows under the heading dynamics (column – Main content) how socio-technical components can misalign at each system level and how IS change can result in multiple, concurrent adaptations to increased variance at multiple system levels. IS change thus can be regarded as a set of heterogeneous and somewhat randomized interventions that seek to de-stabilize, establish, or maintain equilibrium at the building and the work system as to generate design options for the organization that will allow it to adapt to its environment.

A gap can invite two types of responses from the system (Table 1). In the first type, other components adapt incrementally as dictated by the system's deep structure. In his original formulation Leavitt (1964) followed this linear interpretation *only*: socio-technical systems adjust gradually. Perturbations are regarded as unexpected variances, or unexpected misalignments (Mumford, 1983, 2003). In the second type of response, the system will rewrite its composition rules – that is, its deep structure. Weick's (1998) interpretation of reciprocal and circular change clarifies this potential of change: 'Leavitt proposed that these four properties and the causation among them is reciprocal rather than linear', and 'the power of Leavitt's analysis lies in the suggestion of circular causation that is lost when a more linear rational view is adopted' (Weick, 1998, p. 121). Owing to circular causation, systems can move towards increased disarray and reach an edge where they rewrite their composition rules. Because of their recursive organization, gaps can trigger cascading punctuations that escalate non-linearly. Examples of punctuations originating from system components are listed in Table 1. Tables 1a and 1b thus

Table 1 Features of socio-technical systems and their change: (a) Task and actors and (b) structure and technology

Socio-technical component	*Main content*	*Main properties*	*Gaps*	*Dynamics*	*Literature*
(a) Task and actors					
Task	*Work systems*: Task describes the work systems goals and purpose and the way in which the work gets done within the organization. *Building system*: A task is defined through project deliverables and aspired process features in that a development task dictates what developers should accomplish and how in relation to a socio-technical change. *Organizational environment*: Task describes the organization's raison d'etre and the way in which it orients towards and adapts to its environment and meets the requirements and constraints of its different stakeholders.	Task size and complexity Task uncertainty Task ambiguity Task specificity Task stability Time and performance criticality	*Task-actors*: The actors do not understand or accept the task or cannot carry out the task. *Task-structure*: The structure is not aligned with the task or no adequate structure is defined for a given task. *Task-technology*: The technology is not adequate to support the task or it is unreliable or inadequate in its support.	*Incremental*: The more complex and uncertain the task, the higher the likelihood that the system will falter towards disequilibrium. *Punctuation*: The organization's task is radically reformed. Justification for the task is transformed or disappears.	*General*: Leavitt (1964) *IS literature*: Lucas (1982), Beath (1987), Lyytinen (1987a), Curtis *et al.* (1988), Nidumolu (1994), Sabherwal & Elam (1996)
Actors	*Work systems*: Actors include an organization's members and its main stakeholders who carry out or influence the work. *Building system*: Individuals or groups of stakeholders who can set forward claims or benefit from system development. Actors include customers, managers, maintainers, developers, and users *Organizational environment*: Any individual or group that has a stake or can set up a requirement towards the organization.	Personal properties Commitment and skill Differences among stakeholders Wrong expectations False beliefs Non-existent or unwilling actors Unethical professional conduct Personnel volatility Opportunism and personal agendas	*Actor-task*: Actors are expected to carry out tasks which they are not fit or trained to perform. *Actor-technology*: Actors do not understand, cannot operate, or do not accept the technology. *Actor-structure*: Actors do not know the operating procedures, do not accept the structure, or are not aligned adequately with the structure.	*Incremental*: The bigger misalignment between the actors and the other components (task, technology, structure), the bigger the likelihood that the system falters towards disequilibrium. *Punctuation*: Need for radical transformation in the actor's skills, worldview or values.	*General*: Leavitt (1964), Perrow (1979) *IS literature*: Ginzberg (1981), Keen (1981), Curtis *et al.* (1988), Grover *et al.* (1988), Boehm & Ross (1989), Hirschheim & Newman (1991), Henderson & Lee (1992), Markus & Keil (1994), Willcocks & Margetts (1994), Keil (1995)
(b) Structure and technology					
Structure	*Work (legacy) systems*: The structure covers systems of communication, systems of authority, and systems of workflow. It includes both the normative dimension, that is, values, norms, and general role	Level of formality Level of centralization Level and span of control Means of control Allocation of rights and duties Geographical dispersion	*Structure-actors*: Existing or defined structures do not support actors in their tasks. *Structure-task*: The structure is not adequate, well specified or	*Incremental*: The bigger the misalignment between the task and the structure, the more likely the system will shift towards disequilibrium. *Punctuation*:	*General*: Leavitt (1964), Ouchi (1979), Perrow (1979), Damanpour (1991) *IS literature*: Beath (1987), Lyytinen (1987a), Curtis *et al.* (1988), Davis *et al.*

Table 1 Continued

Socio-technical component	*Main content*	*Main properties*	*Gaps*	*Dynamics*	*Literature*
	expectations, and the behavioral dimension, that is, the patterns of behavior as actors communicate, exercise authority, or work. *Building system:* The structure covers formal project organization and decision-making structure, work organization, its workflow and means and channels of communication. It is defined by project management frameworks, methodologies (work organization and workflow) and communication frameworks.	Functional differentiation and specialization	appropriate for the task. *Structure-technology*: The structure is not aligned with the technology and does not support technology operations and use. Structure does not take advantage of the capabilities of the technology.	Transformation or reorganization of key elements of structure: work flow, system of authority or communication structure.	(1992), Markus & Keil (1994), Nidumolu (1994)
Technology	*Work systems*: Technology denotes tools – problem-solving inventions like work measurement, computers, and drill presses that compose part of the work system. *Building system*: Includes software and hardware technology, design methods, tools, and ICT infrastructure used to develop and implement the information system. *Organizational environment*: Includes all elements of the organization's technological core covering production, distribution and R&D technologies.	Functional dimension (production, coordination, control, adaptability) Level of specialization Functional scope and integration Systemic properties (reliability, performance, ease of use)	*Technology-task*: Wrong technology or inadequate technology has been chosen and implemented for a given task. *Technology-actors*: Actors are not capable to operate, use or adapt the technology to the current environment. *Technology-structure*: Technology is not adapted and modified for a given structure.	*Dynamics*: Incremental: the stronger the misalignment between actors and task due to unreliable, inefficient, non-standardized, non-compliant, or functionally limited technology in the work system, the more likely the system will shift towards disequilibrium. *Punctuation*: Disruption in technological basis, discontinuation or radical shift in any of the technological sub-systems.	*General*: Leavitt (1964), Perrow (1979) *IS literature*: Lyytinen (1987a), Sabherwal & Elam (1996) ; Willcocks & Margetts (1994)

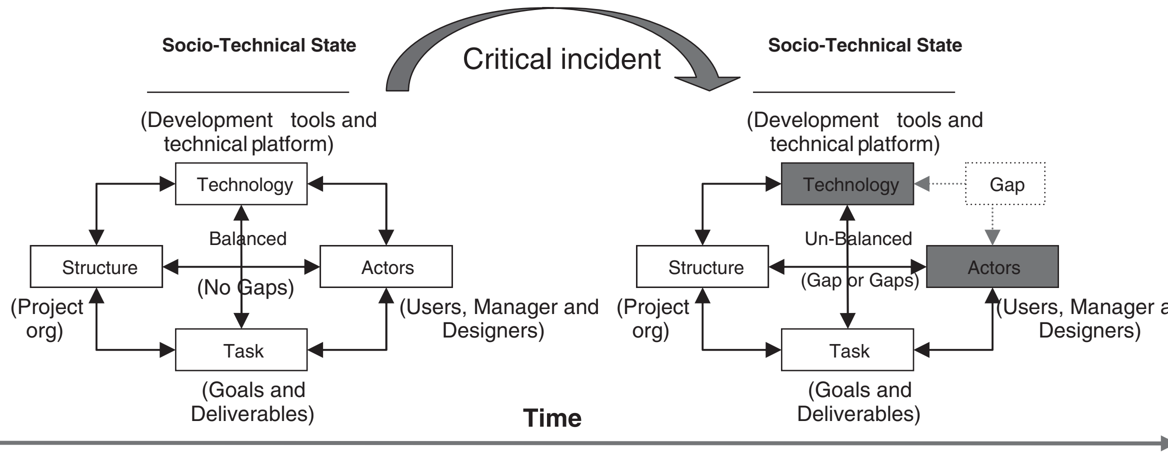

Figure 2 An event model for socio-technical change.

summarize findings form several streams of research, which have worked on 'second-order' theories to explain interactions between socio-technical components.

As noted, multiple studies of organizational and IS change have recognized punctuations at the work system, the building system, or the organizational environment (Tushman & Romanelli, 1985; Tyre & Orlikowski, 1994; Lassila & Brancheau, 1999; van de Ven *et al*., 1999; Garud & Karnoe, 2001; Plowman *et al*., 2007). The way the system responds to a gap depends on its current deep structure – its composition rules and history. Thus, during *punctuation* socio-technical elements and their interactions are re-configured and they afterwards exhibit new, emergent properties. The punctuations echo the system's non-linear and non-deterministic behaviors, which can set the system in a circular, positive feedback-based motion. Attempts to remove these gaps are specific types of *events* called *interventions*. These are measures oriented towards one or more socio-technical elements, or a system that can be controlled or manipulated (e.g. work system) as a whole as to mitigate or remove an observed gap. Events can succeed (i.e. remove the gap), but they can also fail, or even weaken the system's stability. This can be due to failed cognition, the system's complex interdependencies (Cohen *et al*., 1972; van de Ven *et al*., 1999), or an actor's deficient performance. Sometimes interventions fail because of bad luck (randomness). Owing to circularity, interventions can result in unintended second- and third-order effects that produce path-dependent impacts on the system. This can over time morph into an unpredictable wake of change, or stall the system in paralysis.

The proposed multi-level punctuated S-T model satisfies the feature #1 of punctuated change – it can be used to define the deep structure of systems related to IS change. It also meets feature #2 of stability: socio-technical systems seek to remain stable. It also meets feature #3 of systems revolution: it describes both incremental and punctuated change. Finally, the model meets feature #4 – a multi-level explanation: it can analyze IS change at any of the three levels or across levels.

PSIC model

Next we will formulate a vocabulary to describe and explain IS change and build up dynamic and multi-level IS change models. We call it the PSIC model. It is derived using the theoretical framework outlined above about multi-level, punctuated socio-technical change. In formulating the model we adopt process theory, which provides a theoretical rationale to connect socio-technical events during the IS change, that is, how and why the process was organized as it was, and why and how it created the observed outcomes (Mohr, 1982). By anchoring data about IS change into socio-technical events, their timing and order, IS scholars can generate plausible narrative models that describe mechanisms and patterns of change (Langley, 1999). Overall, the PSIC model seeks to abstract and codify features of the 'actual' IS change data by explicating how typical data about events connect to yield observed IS change outcomes.

Components of a PSIC model

The PSIC model depicts IS change as a sequence of changes (some of which are punctuated) organized into a hierarchy of diachronic events. It offers a lexicon consisting of notions like events, event sequences, gaps, components, system levels, interventions and punctuations that are combined into an instance of a PSIC process model that narrates an IS change trajectory. By doing so we follow what Langley (1999) calls a visual mapping strategy, which depicts visually dependencies between events, their environments and outcomes. Thus, PSIC concepts, when organized into visual maps, offer a sense-making device to understand the nature and role of different events in an IS change context, to reveal their significance, and to organize them into why or how explanations. The visual map simply shows how the work system, the building system, and their context evolved over time, why they evolved in the way they did, and why ISD the observed change emerged (Langley, 1999; Pentland, 1999). In a sense, each PSIC model builds an accurate and plausible process narrative about a situated IS change process (Eisenhardt, 1989) that can be later generalized both analytically and empirically.

Thus, the PSIC model portrays IS change as a set of consecutive S-T system states some of which are in equilibrium and others are not at any point of time, connected by events, where some succeed, some fail, and some punctuate. Moreover, in a 'successful' IS change process, the work system *will always* be punctuated, because IS development involves the idea of a deliberate work system change. To narrate this one needs notions of events that will change socio-technical states and string them into sequences as depicted in Figure 3. Each box in the figure represents a socio-technical event showing a path-dependent change in a system at one level. Each event can be read as a possible move in the system's evolutionary path that orders, aligns, or misaligns its S-T components. Each event can either restore the system equilibrium, or fail to do so and the system states following an event can either be in equilibrium or in disequilibrium. The major challenge is identifying events that create gaps, that is, how one can detect from a huge stream of changes, events that truly influence the system. Many times this can only happen with the benefit of hindsight or changing the 'theoretical' lens to explain the change. For example should one record and analyze every small change like an update in software, hiring a new analyst, changing slightly a project schedule which in most cases cannot be considered to be of importance for the outcome. The events must thus share the property that they can generate, sustain or remove gaps, and can also have the potential to punctuate a new deep structure.

The principles for conducting an event mapping for an IS change process are the following. IS change process data is first abstracted into a set of events. These events must meet the criterion of being potentially critical incidents, which could have changed some system states. We then recognize each event's antecedents by tracing the preceding system state (at the same system level) and antecedent changes in other systems that generated the event. Antecedents are defined as a set of temporal and other dependency relationships between the socio-technical elements that preceded the event and could be viewed instrumental (i.e. necessary) in producing it. Each event is thereby connected to its *antecedent conditions* by asking: what conditions were necessary in generating this event? All antecedent relationships for any event will thus trace the whole *system history* up to that point. By doing so, we can obtain the model as depicted in Figure 3 for each level. We can also derive from the analysis of antecedent conditions, vertical interactions showing interventions and non-intended effects from higher levels to lower levels, or events from lower levels that cascaded over time to upper levels.

We will next illustrate the building block that depicts a PSIC event at a more detailed level (Figure 4). It conveys a view of a singular and discrete change in a socio-technical system state. At each system level, the system change consists of sequences of events as shown in Figure 4, and their interactions. The event pairs connect sequentially different socio-technical states at each system level to yield the horizontal analysis.

In the PSIC model events are then contextualized. Accordingly, a PSIC model needs to be expanded with a narrative about the environment. This narrative covers changes in the immediate environment of the building system, and in the organizational environment. The narrative is constructed by analyzing a string of events located in those environmental levels, which show how they vertically produced or interacted with the events in the building and the work system.

Because events have varying impacts on the system state, we must also find out what sort of impact the particular event in this context had on the system(s). First, the archetypal event sequences (Pentland, 1999) such as a progression from balance–imbalance–intervention–balance followed in implementation methodologies (Schein, 1961; Parnas & Clements, 1986) should not be assumed in explaining the impacts. Second, some events can result in multiple changes and need to be modeled as one joint change, or defined separately depending on the desired

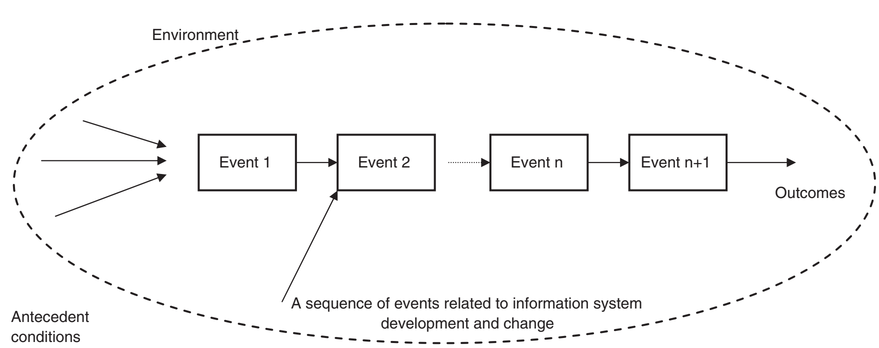

Figure 3 General process model.

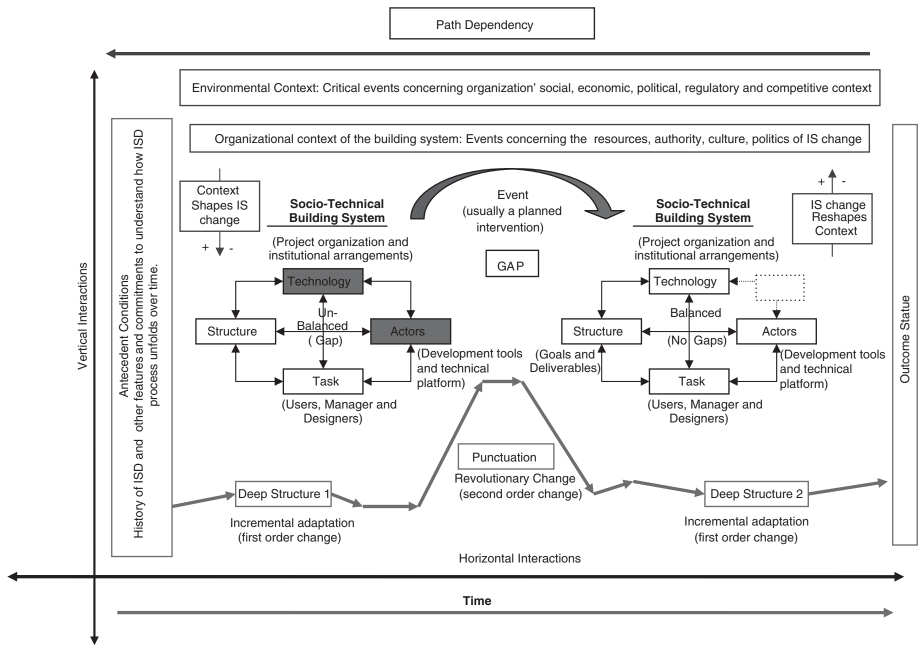

Figure 4 The PSIC model.

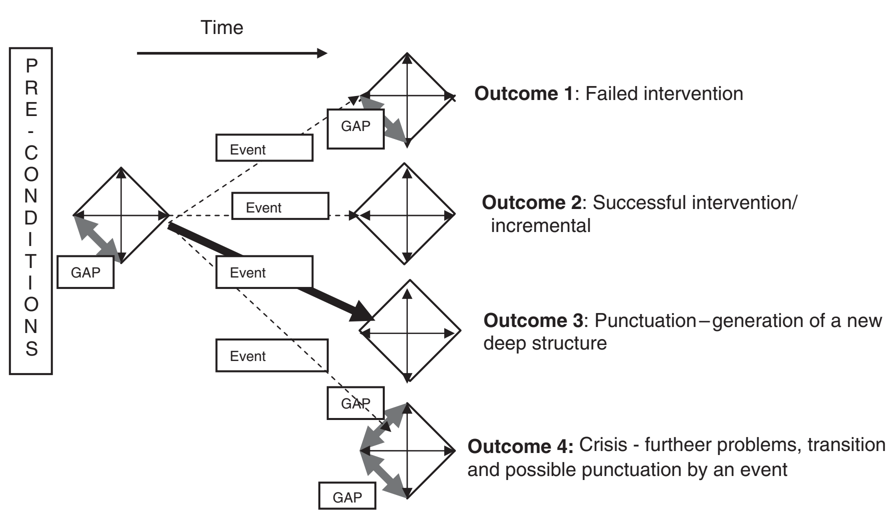

Figure 5 Four types of outcomes from events.

granularity. While doing the impact analysis we need to separate between four types of outcomes (Figure 5): (1) the event 'fails' and the system retains its current misalignment, (2) the event transitions the system into a new equilibrium without affecting the deep structure, (3) the event punctuates the system into a new deep structure; or (4) the event adds new misalignments into the system state. Because these systems involve human agency and retain history, we need to also recognize failed attempts as to explain learning or other path-dependent outcomes.

Because of the multi-level nature of change, any change can start to traverse across levels. Therefore we must depict how systems interact hierarchically (Figure 6). We depict this by a vertical arrow, which will show downwards when a higher level system influences (or seeks to influence) a 'lower' system by intervening in it. For example, a building system must trigger the work system to punctuate when a new technical system is being adopted. We must also show upwards impacts: when the influence flows from a lower level system to a higher one. For example, a punctuated work system will

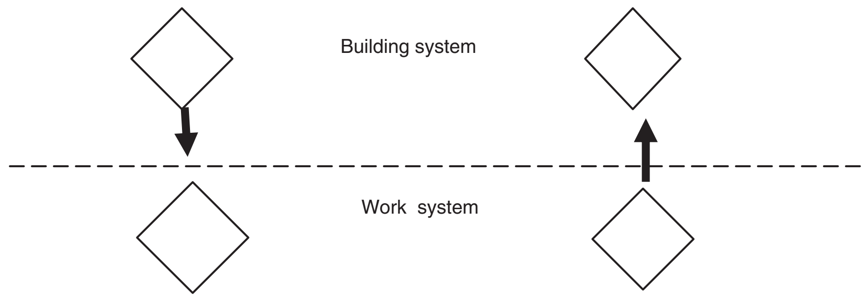

Figure 6 Upwards and downwards – vertical impacts (if the impact fails – no arrowhead).

result in the dismantling of the building system; or a deep change in the work system can lead to a strategic reorientation of the organizational environment.

Building a PSIC model from IS change data

The epistemology employed in building a PSIC model is that of realist ethnography: model builders seek to describe what happened in terms of events and states instead of how people felt about it. A process data corpus can include interviews, reports about changes in work systems, technical system documentation and maintenance documents, changes in organizational charts and other documents, or by direct observation. Typically, events, etc. can be mined from process data using qualitative techniques. Some relationships between events and states can also be derived from extant organizational theory (e.g. relationships between standardized technologies and hierarchical organizational forms). In the end, the proposed process description constitutes some sort of interpretive act (Klein & Myers, 1999).

Each event must be validated by analyzing the scope and depth of its impact, for example an observation of the failure to operate the system, or based on actors' reports (e.g. a quote in an interview). Investigators need to analyze a range of potential outcomes as to recognize the scope and severity of an event's impact. Here, it is crucial to distinguish between incremental and punctuated changes and back them up with data. All events that do not threaten the system operation, or abruptly change its component alignment are seen as incremental, while events that undermine the system, or change qualitatively their operation, or outputs are seen as punctuations.

While analyzing the texts (transcripts, documents, and notes from observations) we advocate in coding using the theoretical terms as suggested by the PSIC model. The PSIC process analysis starts by searching triggers to engage in IS change so as to remove a gap and punctuate the work system, or to use new opportunities to enhance its technological core. Sometimes this can be a necessity to conform to external pressure, or due to vicarious learning. The duration of the analysis is determined by events, which signal when the new work system is either successfully implemented, or the building system is withdrawn and the legacy work system remains intact (Keil, 1995).

The operational steps of the process analysis are shown in Figure 7. During the first step, we chronicle, from subjects' stories, the IS change as a baseline sequence of events (Pentland, 1999). Typically, investigators read the transcripts independently looking for elements that represent critical incidents. They also identify antecedent conditions for each such event. In developing the story the investigator should not attempt to impose his or her view over the data or categories needed and this resembles grounded theory approach (Strauss & Corbin, 1990). We will, however, use a fixed coding scheme that allows us to organize the process data in the theory-based categories. Differences of opinion among actors' stories should be maintained faithfully – even for detected incidents. This results in a relatively long baseline story, which richly narrates events that affect any of the three systems.

As critical incidents accumulate, data from the multiple sources can be coalesced to build a structured narrative (Steps 2 and 3 in Figure 7). This is the critical moment in the analysis as here events are mapped onto types and classified according to the PSIC model into S-T diamonds. While doing the visual coding, investigators often change their interpretations as they identify new gaps or analyze cyclically the interrelationships between events at several system levels and thus evolve in a hermeneutic circle (Klein & Myers, 1999). This, in particular, happens when investigators sort out events into parallel work system and building system events, and identify the first environmental events. Investigators need to also uncover contradictions and puzzles in events. Step 4 looks for evidence about events in the organizational and competitive environments that influenced (mutually or singly) the building system, or the work system. The final analytical step involves compiling a visual map of the IS change in the form of a PSIC diagram where relationships between the events and gaps can now be detected and identified in bold, thicker lines. An example of such a diagram is depicted in Figure 8 for a data set that was used by Robey & Newman (1996) (see the Discussion in the next section).

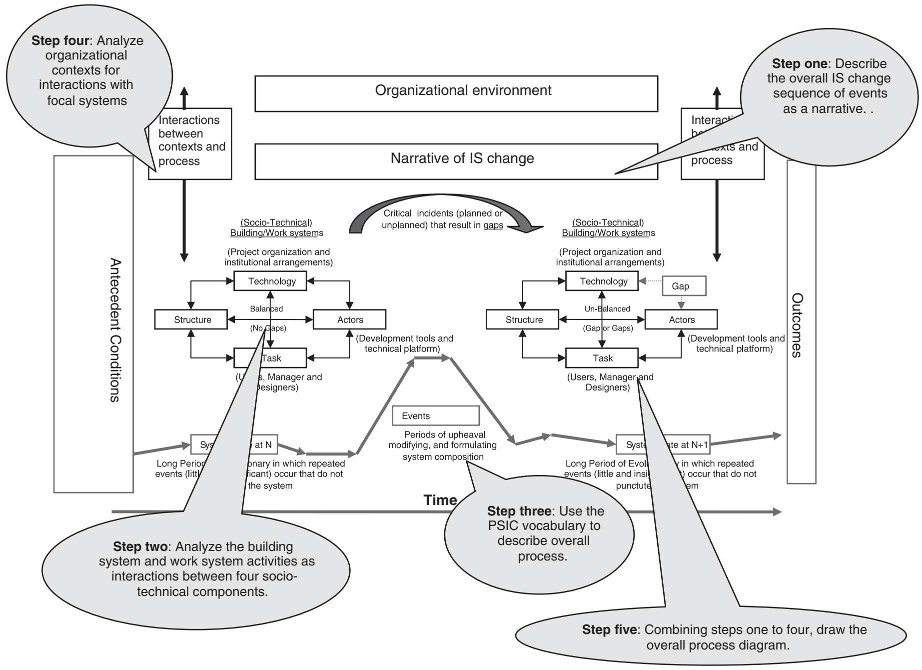

Figure 7 PSIC analysis steps.

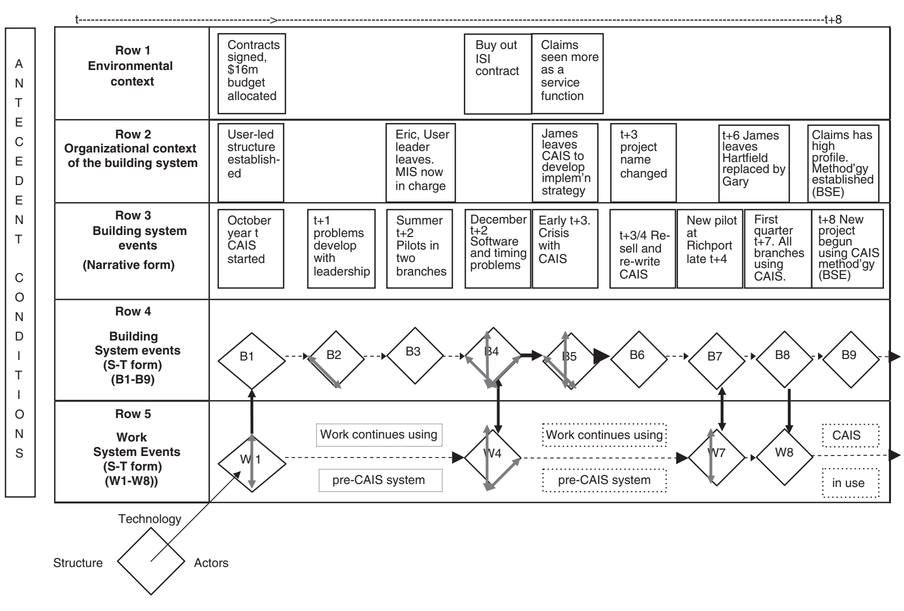

Figure 8 PSIC model of CAIS change adapted from Newman & Robey (1992) from t to $t+8$.

Illustration of the use of PSIC model

To illustrate the value of the PSIC model in explaining complex IS change we will next apply it in accounting the same IS change process and its outcomes as analyzed by Newman & Robey (1992) in the development of their well-known social process model (SPM) (Figure 8). We chose this example, because Newman & Robey's (1992) SPM has clear affinity with the PSIC model: it draws on process theories, and is quite explicit about using Gersick's idea of punctuation. At the same time it is more limited in its scope and selection of the change content: it only covers social processes (actor–actor relationships) at the building system level. To do a fair comparison we revisited their original CAIS case data

(Hartfield Insurance) and drew upon this data set in deriving the respective PSIC model for it.

In Figure 8 we recast the CAIS data using the PSIC model. In Figure 8, row 1 represents significant events in the environment. For example, the change the competitive environment indicates that insurance claims was seen at Hartfield as a service function rather than a cost to be minimized. This was significant when it came to 're-sell' CAIS application: while the designers kept the acronym, the system was re-titled as Claims Automation for Improved Service replacing the original title, Claims Automation Information System. Row 2 illustrates the organizational environment of the building system including the entry and exit of key personnel, and changes in resources, scoping, mandates, etc. Row 3 identifies in a brief narrative form the critical events in the building system. These are repeated as S-T events in row 4 in the form of S-T diamonds. These are sequenced and labeled accordingly as B1, B2, etc. The thick black lines within diamonds represent the researchers' agreed judgments of gaps that arose between the socio-technical elements at those moments of the system evolution. For example, in diamond B2, Eric the user-leader experiences a crisis in leadership (a gap between people and structure), which is resolved when he steps down from that role. His place is taken by one of the MIS people (James) and this intervention resolves that issue (but was not mentioned in the original SPM description). Multiple gaps can occur simultaneously as can be seen at B4 and B5. Overall, the number of thicker lines indicates the growing severity of the crisis, in this case, an outcome of ongoing and severe technical problems with the software.

The lowest row – row 5 – shows the S-T events in the work system which are labeled consecutively as W1, W4, etc. They correspond to the numbering of events in Row 4 and portray the way the work system interacts with the building system and evolves. To illustrate: in W1 there is a gap between the claims' task and the technology they use (i.e. the system needed updating). This is the trigger which, once the problem was recognized, resulted in initiating the CAIS project, whereby the budget was allocated and the building system was launched. This is shown by the upward pointing arrow from W1 to B1. When, after many years (eight), the CAIS system was finally delivered, this is shown by a downward pointing arrow (B8 to W8). Where there is no interaction between the building system (Row 4) and the work system (Row 5), the pre-CAIS manual (legacy) system continues to function.

Newman & Robey's (1992) SPM model focuses on the status of the binary social relationship between the system analyst/designer and the principle user(s), that is, actor component in the building system. It analyzes the history of that relationship as reflected in leadership structures as one of joint development, analyst-led development, user-led development, or no significant pattern. In the case of the Hartfield, Newman & Robey (1992) judged the history of development as analyst-led, which had produced low credibility in the user community (p. 261). Claims and responses with regard to this relationship in the building system are depicted in their process diagram as *encounters* that can result in one of three process states: acceptance of the claim; equivocation; or rejection in relation to the system to be built. In between each encounter, the consequences of these encounters are played out as longer, stable periods called *episodes* where change occurs incrementally, whereas encounters are punctuations where a 'revolutionary upheaval' takes place (Gersick, 1991). The visual model of SPM shows punctuations between stable periods. The events in the Hartfield insurance case are depicted an IS change process that begins with acceptance which continues for a period. The building system then hit severe technical problems during the pilot tests that challenged the system's viability demanding a re-selling and re-writing of the system during which the users were judged to be equivocal. This was turned-around after the re-write, and the system was eventually delivered successfully (i.e. judged as an acceptance).

The SPM involves one level of analysis – the state of the building system (the project) – and it recognizes just one dimension in that system – the status of its 'actor' relationships. Owing to its limited focus, the SPM highlights critical interactions between the analyst/designers, and the users. The researchers are expected to label these encounters and interpret their outcomes as critical incidents that result in one of three states. As a result, although at the Hartfield the users were heavily involved in the development and testing of the new system, the model treats the work system and the actual users as peripheral to the observed outcome. The focal point is the ongoing status of the actor relationships. Similarly, in the SPM, the organizational context is acknowledged only in passing has no critical impact on the unfolding of the process. As a result, after the analysis we do not know the actual process by which the identified encounters or other events produced IS changes. In this sense the building system changing and producing interactions at the work system is 'closed boxed' and remains 'unknowable'.

The key features of the two models are summarized in Table 2. In the PSIC model the events are analyzed as socio-technical changes on three levels. The model uses these levels, the notion of evolving contexts (internal and external) and their interactions to narrate event sequences that resulted in the final outcome. It portrays IS change as a continual interweaving of internal and external events that the development staff, users and management deal with – mainly reactively, sometimes proactively – and not always successfully. In contrast, the SPM does not assume multiple levels of change and does not apply socio-technical theory in caricaturing IS change. Rather it focuses on the binary actor relationships within the building system. This has significant consequences for the scope and outcomes of the

Table 2 Comparing the SPM and the PSIC model

SPM, e.g. Newman & Robey (1992)	*PSIC model*
Level of analysis: One – the building system *Context*: Yes, but implicit and not elaborated *Punctuations*: Yes – mostly implicit as encounters *Social-technical modeling*: no *Closed boxing*: Yes – focuses on the interactions between designers and users but the process is unknown *History*: Yes – but confined to history of system design leadership patterns. Patterns can be reproduced *Process*: Yes, but confined to episodes and encounters between designers and users *Interventions*: Not explicit *Outcomes*: Derived from antecedent conditions and process *Process diagram*: Simple – Three states (acceptance, equivocation, rejection) and one of four antecedent conditions. Diagram shows where the relationship between designers and users breaks down	*Level of analysis*: Multiple – Building system, Work system and contexts *Context*: yes. Organizational and external contexts *Punctuations*: Yes and explicit first order incremental changes and second order 'revolutionary' or step changes within and between the system levels. *Social technical modeling*: Explicit (actors, technology, structure, and task). Instability, gaps and interventions *Closed boxing*: Yes – interactions between the four social technical model elements form the part of the model that we can describe but the internal process of change cannot explicitly revealed *History (antecedent conditions)*: Yes – at multiple levels (building and work systems) and not confined to design leadership patterns. Patterns path dependent. ISD 'form' offers the possibility of developing a diagnostic tool to assess the risk of proposed project *Process*: Explicit and broadly defined using S–T diagrams *Interventions*: Four explicit and detailed types of interventions (Figure 5) *Outcomes*: Same as SPM but adds detailed contextual issues; defined as a set of socio-technical states *Process diagram*: Multiple STS diagrams at two levels, first- and second-order punctuations and explicit process contexts. Gaps, their number and persistence represent a measure of building/work system challenges, which *ex ante* can be used as a diagnostic tool for learning.

subsequent process analysis. SPM remains relatively simple and quick to construct and shows graphically how claims about the system transition over time. Indeed, researchers could start by drawing the SPM, and supplement it with a richer PSIC model as they go along.

The PSIC model is more comprehensive and elaborate, that is, theoretically accurate as it allows us to paint in the detail of the dynamic life of this complex IS change process. The PSIC model identifies multiple sources of change – technical/structure, or actor technology interactions – in *addition* to how actors relate. It also goes beyond analyzing actor's *conscious* reactions during the change process (Newman & Robey, 1992; Newman & Sabherwal, 1996) by delineating dynamic interactions within and between the work and building system levels. This co-contextualizes IS change into multiple levels whereby the PSIC model can detect 'invisible' socio-technical influences operating behind actors' backs. One example of this is the difficulty in predicting the future system performance in CAIS, that is, the potential actor–technology gap in the work system. This is something that hitherto has been mostly noted in passing in IS change analyses with a notable exception of Orlikowski & Hofman's (1997) study. Their emergent change concept is similar to our notion of incremental change in the work system; while their planned/opportunistic change is similar to the idea of punctuation in the work system. Their analysis does not, however, detect mechanisms that generate these changes at multiple levels (other than referring to organizational learning).

In the PSIC model, major imbalances between socio-technical elements are shown as gaps and the number of these gaps and the period over which they persist indicates the severity of the problems faced and the greater the need for intervention. These interventions can show patterns over time of either an improvement (fewer gaps), or an escalation or a likely punctuation (more gaps). This can be used then as an *ex ante* diagnostic tool to learn (1) what can go wrong in projects, (2) when to intervene, and (3) what interventions work when and why. In contrast, the SPM model offers no such means: it does not illustrate the unfolding trajectory of the system change within the work system or the building system.

The variation in socio-technical interventions is recognized directly in the PSIC model (Figure 5) while SPM does not offer any notion of an intervention. At the system level, the outcomes of PSIC interventions draw on distinctions essential in Gersick's theory (1991) while the SPM views punctuations only at the level of actor's relationships. These, in contrast, are not regarded as punctuations at all in the PSIC model. Also, in contrast to the SPM model, the PSIC model with its multi-level, multi-dimensional analysis elaborates simultaneously the nature of the first-order incremental changes (e.g. B3, B7), the second-order 'revolutionary' changes (interventions/ punctuations) such as B4–B5 at the level or building systems, *and* between systems like in B1 (initiating the project), and B8 (changing the legacy system to the new CAIS system). Overall, in the PSIC model the socio-technical elements become the boundary for the 'closed-box' analysis. The analytical focus is thus centered on the critical relationships in the S-T diamonds as a means to assess where the gaps can appear and disappear, and how they can cascade across levels.

The histories of the building and work systems, and external environment are integrated within the PSIC model with its concept of antecedent conditions. In the CAIS example, this reveals that a history of failure of ISD in Hartfield represents a development 'archetype' which, when not dealt with radically, was likely to be reproduced. This alone is a significant theoretical improvement over SPM, as the PSIC model offers a possibility of using prior patterning as a diagnostic tool. At Hartfield, had they not adopted radical change to the ways they built systems, we would have predicted that the CAIS project would have repeated the failure of the past projects. As it was, Hartfield employed a new user-driven method, new liaison staff, the model office, new office technology, etc. and although the system was delivered five years late and was four times over budget, it was still judged to be a success! Moreover, the PSIC model suggests that the outcomes of IS change at any level become part of the cumulative history of system development. This was vital at Hartfield when the user-driven development method was adopted later to develop other systems. In the end, this was perhaps even more important than the success of the CAIS system: it helped break the endemic cycle of failure.

The notion of the context used in the PSIC model also reveals that during large IS change, crises are normal: the essence in understanding IS change is to understand how the building system reacted to crises. This escapes from the SPM analysis, as it does not recognize the dynamics of change at the system level. Most crises emerge unexpectedly at the system level as so-called 'Black Swans' unrelated to change process *per se*, but deadly critical in shaping the change (Taleb, 2007). For example, the competitive pressure on the Hartfield drove the organization to launch a project hastily that would make its claims processing more efficient. To do it quickly it brought in an outside software supplier, though later this proved to be a costly mistake. But, at that point it was time to re-sell the same change idea and the leadership team 're-engineered' the project name to reflect the new service ethos popular in the environment. Thus, the PSIC process model thus helps trace the trajectory of a building system change in a broader context and show how the performance of the building system related strongly to its past outcomes, and the current rhetoric of success in the environment (Keil, 1995). For example, analyses of escalation focusing solely on the events in the building system offer somewhat simplistic explanations of the phenomenon: many strategic system initiatives cannot be abandoned prematurely due to contextual influence. This just compounds the organization's main problem (like the *need for a* CAIS system never went away). The observed need – the gap – for developing the new system will persist in the minds of managers, and the time and budget overruns will escalate as long as the gap stands (Keil, 1995). Therefore, escalation analyses might benefit from a broader approach to assess the overall dynamics of the context associated with the IS change.

Overall, the PSIC model offers promising ways to understand the *patterning* of socio-technical events across systems and how they affect the IS change, that is, under what conditions do the observed patterns create path dependencies (Van de Ven *et al.*, 1999; Garud & Karnoe, 2001)? Such trajectories have been investigated in studies of escalating commitment (Keil, 1995, Drummond, 1996a, b). Organizations start to run one project after another with the same solution, but with different problem formulations. History repeats itself first as a tragedy and then as a farce, as Marx put it. Change in patterns also shows how preceding IS changes becomes the antecedent conditions for new building efforts leading organizations to get mired in repeated patterns of failure (Lyytinen & Robey, 1999). This has parallels with many human activities including those of competitive sports, for example soccer, or in criminal trials, where the past is used to predict future behavior or performance. As in soccer or baseball, a bad run of 'form' is often followed by a major change to personnel and playing formations – the sort of punctuation seen after a failed development effort (e.g. Keil, 1995; Drummond, 1996a).

Discussion

We will assess the contribution of the PSIC model on two fronts: (1) by evaluating the PSIC model with regard to other change models, and (2) by positioning it as a richer, middle-range explanation of IS change.

Evaluating the PSIC model

PSIC model expands earlier *research on socio-technical change* (Mumford, 2003; Alter, 2005). In particular, we complement Alter's (2005) approach, which articulates how to model IS change as part of a work system change, and how to conceptualize IS change. His approach offers a rich vocabulary to analyze IS change as part of the change in work systems, but does not convey ways to characterize IS change as a set of punctuations. He does not use socio-technical concepts symmetrically at all three levels as his emphasis is not in explaining IS change. However, we find that his ontological model offers a promising way to expand the socio-technical model at the work system level.

Recent IT strategy research has applied socio-technical theory to explore strategic change as an emergent and punctuated change (Yetton, 1997; Sabherwal *et al.*, 2001). These studies suggest that the realized strategy springs from complex and dynamic interactions between an organization's socio-technical elements (Yetton, 1997) and its organizational environment. These interactions do not follow a linear logic of aligning technology directly to task (strategy) as suggested by Scott-Morton (1991), but admit punctuations. The multi-level analysis of the PSIC model offers, however, a richer way to analyze co-evolutionary events not recognized in the single-level

IT strategy models (Yetton, 1997). It also adds the concept of punctuation in characterizing strategic change as suggested by Sabherwal *et al*. (2001). In addition, the dimensions used in the Sabherwal *et al*. (2001) study are similar to the four S-T elements. They also observe longer periods of non-alignment (disequilibria), reluctance to punctuate until a crisis looms, the final inevitability of punctuations, and actors' limited cognitive capabilities.

The PSIC model expands the analysis of IS change as punctuated change with the notion of socio-technical punctuations by highlighting the S-T 'engine' of the IS change. Several earlier studies have applied punctuation in analyzing IS (Newman & Robey, 1992; Newman & Sabherwal, 1996; Robey & Newman, 1996), or in describing the dynamics of use (DeSanctis & Poole, 1994; Tyre & Orlikowski, 1994; Orlikowski, 1996; Orlikowski & Hofman, 1997; Lassila & Brancheau, 1999; Majchrzak *et al*., 2000; Black *et al*., 2004). As already noted, these studies do not recognize interactions between the work system and the building system, and suffer from a relatively *ad hoc* classification of change mechanisms. In this regard the PSIC model broadens mechanisms that shape both the system change and its use. Finally, these studies analyze changes in one dimension only – either the actor–actor relationships (Newman & Robey, 1992), or the actor–technology relationships (Orlikowski & Hofman, 1997). This is significantly expanded with the PSIC model, which recognizes all types of interactions between the four socio-technical elements. The limitation of the PSIC model in analyzing these interactions is that it does not offer means to analyze systematic interactions between events over time and the resulting emergence of system change trajectories. Such analyses are commonly carried out through simulation studies, which recognize feedback and complex interactions between system components (see e.g. Abdel-Hamid & Madnick, 1989, 1990, 1991; Black *et al*., 2004).

The PSIC model assumes *chaotic and random behaviors* in social systems: change is essentially non-linear, complex, non-deterministic, emergent and path dependent (Mohr, 1982; van de Ven & Huber, 1990; van de Ven *et al*., 1999; Agar, 2004). Thus, all socio-technical systems associated with IS change share a degree of complexity in that they are composed of elements that interact in unpredictable and non-linear ways. Systems are therefore emergent. Finally, they are also path dependent (Cilliers, 1998) in reproducing their deep structures (Cyert & March, 1963; Newman & Robey, 1992). This characterization allows us to observe, however, simultaneous causal tendencies and chaotic or random *patterns* of change (van de Ven *et al*., 1999; Jacucci *et al*., 2006). In the case of causal behaviors, a change in a socio-technical element can precede and cause changes in other socio-technical elements. In the case of chaotic behaviors the change exhibits regularized patterns of behaviors over time, but such behaviors cannot be attributed to a single cause, and different causes may produce the same outcome. Random behaviors have no observable regular patterns and system outcomes and processes remain unique and non-predictable (van de Ven *et al*., 1999). Causal tendencies point out the most likely responses to typical events by a stable system in a stable environment. Chaotic or random patterns are borne out of instability at each system level, of multi-path interactions between levels, or of abrupt changes in higher levels or in the environment. One reason for the presence of chaotic and random behaviors is *human agency* which forms part of each system level. Actors can at any time deviate from path-dependent behaviors and this can propagate other changes in the system (Giddens, 1984).

In recent complexity discourses, change is also seen to be continual in that the system is never at rest (van de Ven *et al*., 1999; Axelrod & Cohen, 2000; Agar, 2004). Complexity theory distinguishes accordingly the frequency and magnitude of system change which – when represented in a log scale – show that small changes are frequent, while punctuated changes are rare but exhibit what is called Mandelbrotian uncertainty (van de Ven *et al*., 1999; Taleb, 2007). This suggests that a power law metric could be applicable to identify critical events that influence to various degrees IS change and punctuations.

Recursion in the systems also implies that higher level changes are less frequent and more drastic, but interact constantly with lower level changes. The PSIC model recognizes the chaotic feature in systems: small changes at lower levels originating from *bricolage* (Ciborra & Lanzara, 1987) can, in turn, escalate into broad changes producing butterfly effects. We admit such effects in the PSIC model by analyzing hierarchical interactions and related gaps. Likewise, in the PSIC model we assume that some events can become so-called 'Black Swans': that is, they are unanticipated, sudden and abrupt (Newman & Robey, 1992; Keil, 1995; Drummond, 1996a, b; Taleb, 2007). This is an exemplar, *par excellence,* of the inherent complexity of IS change: it involves events that rarely occur and seem to randomly intervene. But when they do, they can overwhelm the processes. The new competitive climate, the coming and going of managers, unexpected technologies, etc. can all conspire to make a well-planned IS change falter. Therefore, the PSIC model does not admit deterministic explanations of the IS change: the impacts of any event remains uncertain until the impacts have been realized. Likewise, agents' responses are non-deterministic and involve high variance. The model therefore recognizes the possibility for a contextual narrative – a process theory – which embodies the context and the history of critical events at several levels. This narrative helps traverse through specific junctures called plots in the developed narrative (gaps in our model) in which the narrative can go into any of the alternative trajectories.

Because of the rarity and Mandelbrotian nature of uncertainty, *system developers* rarely *learn* from their past as to inductively infer successful change patterns and to learn about their causes (Lyytinen & Robey, 1999; Taleb, 2007). This blindness is partly due to the difficulty of making sense of complex environments (Weick, 1995a; Taleb, 2007). Therefore blunt failures in actors' learning are common (Keil, 1995; Drummond, 1996a) and designers constantly orchestrate *ad hoc* and even *superstitious* interventions that rest on authority, legitimacy and herd effects (Keil, 1995; Drummond, 1996a; Taleb, 2007).

Overall, the complex and chaotic view of change underlying the PSIC model makes its *ontological* and *epistemological stance* close to that of critical realism (Bhaskar, 1978, 1979; Dobson, 2001; Mingers, 2004a, b). Socio-technical systems and deep structures act in the real domain of mechanisms that generate events in the empirical domain, some of which can be recorded and interpreted by actors (and investigators) in the epistemic domain. The model's idea of a system organization and their open nature, and actor's limited and voluntary behavior are in accordance with critical realism's view of social reality. The idea of using simplified though relatively complex models and somewhat fixed vocabularies to understand with hindsight *why* certain outcomes emerged is also in line with critical realism's idea of social theory as a means to improve the explanatory power of our record in the epistemic domain. Likewise, the PSIC model honors epistemic modesty associated with critical realism: no investigator has the omniscient knowledge about all incidents and their consequences and thus falsification rules. Therefore multiple explanations are possible for the same process data and we can only say which ones are wrong rather than saying which ones are surely right. At most, we can expect *plausible explanations* based on justified reasons that can be falsified at any point of time. These warrants can be developed by trying to identify all events, grounding their impacts on recorded system states, and analyzing and excluding alternative explanations of how and why change unfolded in light of evidence.

So far we have *applied the PSIC model* to investigate multiple and complex IS change trajectories as to better understand the dynamics of such IS changes and the role of punctuation in them. These analyses have yielded surprisingly rich explanations as to why and which event sequences lead to specific IS change outcomes, why specific interventions lead either to improvements or crisis, and what role path dependency played in shaping IS change (Lyytinen & Newman, 2008a, b). We have observed also that change patterns lead often to divergent IS change: crisis, chronic intervention, or successful punctuated change. Our experience is also that mapping the IS change data into the PSIC model is not that difficult – we have had several M.Sc. students carry out such analyses with significant insights without any major difficulties. Our experience also shows that the derived PSIC model can also be integrated and analyzed in light of other theories for example Actor Network theory (Lyytinen & Newman, 2008a), or learning theories (Lyytinen & Newman, 2008b). As we continue to carry out such process analyses, we also expect to start detecting common patterns that would suggest generalizable process explanations, and help expand and articulate better the core logic of process explanations. One approach is to extend these analyses with structural network analyses or simulations to yield more generalizable dynamic models.

The PSIC model also has several *limitations*. First, collecting process data to carry out the PSIC analysis is burdensome and in most cases can only be done after the fact when there is the benefit of hindsight to really understand the criticality of different events. Secondly, we can expect to face coding ambiguities as to which events will count as punctuations and which events lead to which outcomes, or how to code interactions between events and states at different levels. Third, there is also the additional methodological burden as to whether the derived socio-technical models truly reflect the deep structures of the examined systems. Currently, there are no clear criteria to decide what are the typical or expected features of deep structures. However, our experience of using the PSIC model over several years has taught us that by deriving the process model in a team helps alleviate most ambiguities associated with the correct coding of the data and to discover the true impact of different events. The situation here is no different than the situation any historian faces. The burden of what are the true deep structures is, in practice, not that severe as the PSIC analysis has always led to a deeper appreciation and understanding of the IS change than would have been gained without it. Whether these PSIC diagrams are truly reflections of deeper structures underlying change may require larger samples and more careful analysis *across* those samples to highlight the generative forces that underlie change. Fourth, theoretically we in principle treat the gaps within levels and between the levels in symmetric way. Yet, the analysis and representation focuses more on gaps within the levels as such representations are simpler. They help organize a three-dimensional change process in a two-dimensional space. But at the same time the richness and the theoretical need to also analyze gaps between the levels in a symmetric way is lost. We seek to improve this in the future revisions of the model and its visualization technique.

PSIC model as a closed box

We define closed-boxing as an intellectual strategy whereby the chosen abstraction principles lead to a closing or hiding – by conceptually excluding (blinding) – pertinent features of the change from the inquiry by choosing a specific conceptual taxonomy (Pinder & Moore, 1979). This has been also referred to as black-boxing in the literature, but we felt that this term is an inappropriate description of the intellectual process involved. As Wittgenstein put it: 'What we cannot speak about we must pass over in silence'. In other words closed-boxing refers to the degree of explicit description and explanation of change that the chosen model of the IS change admits. In the past, closed boxing admitted by

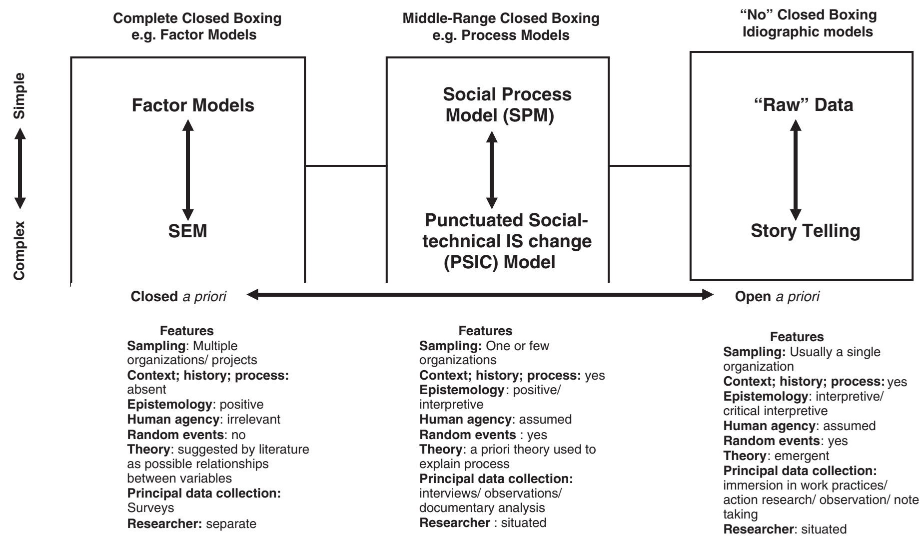

Figure 9 Types of closed boxing in explaining the IS change.

the proposed IS change models has led to focus on linear and incremental change on a single level, and to negate the possibility of punctuation. The critical thing in such closed boxing is the following: which sort of closed boxing is beneficial for which type of explanation about the IS change? In this regard we argue that the PSIC model offers some innovative ways to closed boxing that permit more accurate middle-range analyses of IS change.

Figure 9 elaborates how closed-boxing affects researcher's view of the IS change. It locates the process models, the traditional factor model, and detailed ethnographic (idiographic) models of IS change on a scale from totally open to totally closed explanations of IS change. In this regard, at the one extreme there is no (or very little) closed-boxing, and every possible form of accounting for change is admitted, that is, the language is unbounded. Ethnographic researchers/action researchers mostly fit this category as they pursue extensive 'raw' data gathering in a single organization and there is little theorizing *a priori* (e.g. Pettigrew, 1985; Orlikowski, 1993). Such approaches use 'thick' idiographic descriptions and the researcher is immersed in experiencing the IS change. In its simplest form, any data are considered as a possible candidate for collection including contextual, historical and process data. The data and associated change process are presented with little theoretical editing and coding as to convey a local and unique narrative (e.g. ethnomethodology; Garfinkel, 1987). In such narratives, random and curious events can be seen as highly relevant and critical for the success of the analysis. In its pure, complex form, researchers want to tell the story of the IS change as an historical narrative as they see it.

At the other extreme – with complete closed boxing – the IS change process explanation admits only stories about states and their relationships, while remaining silent about actual change processes and evolution. This is the realm of factor models, which draw their epistemological foundations from the positivist view of science. Factor models use survey or other measurement-oriented instruments to poll organizations about their IS change processes and represent them as sets of vector states and their relationships to suggest a causal depiction of IS change processes and what factors drive them (Sabherwal & Robey, 1995). The models and the variables of interest are derived from the past literature and are fixed prior the study. The variables represent vector spaces and their changing relationships (over time). The studies link statistically vector measures of process outcomes (the dependent variable(s)) with independent antecedent variables like structural or actor characteristics, or process characteristics (e.g. use of participation, process methodology used). Change is assumed to be incremental and linear (or sometimes quadratic) represented in correlations between independent (mediating) and dependent variables, and they are seen to reflect deterministic tendencies. The mappings from antecedent states to final states are evaluated for their statistical significance, power and explanatory strength (e.g. R**2, size effects). Because of the sampling and the instrumentation these process accounts assume a common context, lack any idea of history, and are devoid of any sense of a process of change. The so-called random events or qualitative changes are either included as part of the measurement error, cannot be addressed at all due to the fixed nature of the measurement models, or at the worst, dropped from the analysis as outliers. Yet, such factor models can be useful in describing tendencies of IS change in populations as they produce generalized glimpses of tendencies in samples in the form of significant correlations. These can be then used to justify or ground parts of process explanations: for example how chosen socio-technical factors can interact to influence specific states.

Process models advocated in this study – like the SPM and the PSIC model – fall somewhere between the total lack of closed-boxing and total closed-boxing. For this reason, we label them as *middle-range* closed-boxing (Merton, 1968). The models have affinity to many of features of ethnographic research: they rely most often on small samples with the explicit recognition of contexts, history, and process. They also admit random and chaotic change and recognize curious chance events that abruptly affect the change. In one sense the degree of closed-boxing is determined by the aspired level of complexity of the analysis: investigators can apply either quite simple process models like SPM or more complex models like the PSIC. The choice is dictated by the research trade-offs that emerge as investigators make choices about the scope of their theory (generalizability), forms of explanation (simplicity), and the desired level of accuracy and completeness to record the nuances of the change (Weick, 1989, 1995b). Such choices need to be made explicitly within middle range models (e.g. SPM *vs* PSIC model), but similar choices appear also in factor models when an investigator needs to choose between simpler forms of regressions and more complex structural equation modeling techniques. Likewise, in idiographic analyses, investigators need to make choices how far they want to move from simple and flat raw data to more complex grounded models of change with more abstract vocabularies. However, the spectrum of choice is broader and made more visible with middle-range process models like SPM or PSIC.

By being part of middle-range theorizing, the PSIC model offers some ways to adjust with flexibility the desired level of closed boxing. In the case of the SPM, the process model is formed by the binary interaction between the analyst and the user. We can then describe results of this interaction, while the explicit change process remains unknown. In the more complex PSIC model the S-T diamond becomes the boundary of closed-boxing. We can describe the results of the interaction of the socio-technical elements (e.g. gaps), but their detailed interaction remains opaque. Somehow this can be removed by adding new categories to the S-T model or generating more refined connections between the components. In this regard, the proposed process model forms essentially a theoretical skeleton that guides how to pursue data and to guarantee its completeness. But the anatomy of the skeletons can be extended and organized even during the study. But, in contrast to idiographic models, the PSIC offers as skeletons explicit *a priori* models on which to hang the data and how to enclose the data with theoretical categories. In the end, a middle-range theory of IS change is built by showing how the recorded data are coded as events that fit with the emerging and dynamic set of categories that help explain why and how these events resulted in observed IS changes.

The main contribution of the PSIC model in deriving middle-range theory is that it offers an integrated and theoretically grounded, but at the same time a relatively complex, way to analyze the IS change. By being positioned as a relatively accurate middle-range theory with a relatively complex vocabulary it offers benefits for process theorizing, which other proposed models of IS change do not suggest. First, it lays out a theoretically grounded richer vocabulary to build local, accurate and relatively complex process theories that are simply unknowable within any factor model. Unlike factor studies, the PSIC model helps produce accurate theories of IS change in which generative mechanisms of the IS change are laid more bare. It can also be integrated with factor models by drawing upon 'second-order' factor theories that show why some events or socio-technical states 'cause' certain types of change. How to integrate these second-order theories into the PSIC model is, however, beyond the scope of this paper. Finally, by being relatively complex the PSIC model offers a means to determine dynamically the boundaries of closed-boxing not available in ethnographic accounts. It thereby offers a systemic language of IS change that admits analytically to generalizations across multiple process accounts. This points towards more encompassing theories of dynamic, punctuated IS change that find application across ISD processes and contexts.

Conclusions

In this essay we asked three questions: (1) what is the scope of IS change and how to describe organization and properties of systems that are involved in IS change?, (2) what is the nature of the change in systems associated with IS change?, and (3) what is the content and engine of these changes and how do they work as a socio-technical phenomenon? To address the first research question we formulated a multi-level view of IS change. To address the second question we adopted theories of punctuated equilibrium to characterize IS change. To address the third question we formulated and expanded a punctuated theory of socio-technical change. Based on these analyses we drew upon process theories and formulated a PSIC model of IS change. The proposed model depicts IS change as a subtle interplay between technologies, actors, organizational relationships, and tasks at multiple levels. The change can be either incremental or punctuated and it is co-evolutionary in that it distinguishes multiple separate, but interacting streams of events – the work system, the building system, and the organizational environment. Any of these socio-technical systems has the potential to inject gaps that will trigger interventions into the focal systems leading occasionally to punctuations. We also discussed their usefulness in explaining IS change as a multi-level, punctuated change and how it relates to other studies of IS change.

Currently, there is too little research on the dynamics of IS change that utilizes simultaneously ideas of incremental and punctuated change and multi-level view of change. We hope that the proposed PSIC model is a step towards richer and more detailed accounts of what are increasingly complex IS changes and their corresponding organizational design options.

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Appendix

See Table A1.

Table A1 Glossary of key terms

Construct	*Meaning*
Agency	As parts of socio-technical systems humans can deviate from law like regular behaviors that can propagate changes throughout the system and its environment. Owing to human agency socio-technical systems exhibit learning and are path dependent while making choices during their adaptation.
Antecedent conditions	Necessary and sufficient conditions to trigger an event.
Building system	A socio-technical system – separated by space and time from work system – that commands and enacts a set of resources and routines through explicit rules and regulations and tacit and embedded competencies of individuals to generate IS change.
Complexity	An emergent property of socio-technical systems made of large numbers of self-organizing elements that interact in a dynamics and non-linear fashion and share path-dependent history.
Critical incident	An event that results in a gap.
Deep structure	The set of fundamental 'choices' a system has made concerning the basic parts into which its units will be organized, and the activity patterns and interactions that will maintain its existence.
Environmental context	An environment, which covers the organization's social, economic, political, regulatory and competitive environments and which influences and is influenced by all other systems during IS change.
Event	Any change in the system state that can be observed.
Gap	A property of a system state that affects systems' behavior and its repertoire of responses. A gap is any situation in the system, if left unattended, that will deteriorate the system's performance, or threaten its long-term survivability.
Horizontal analysis	A process of analyzing interactions at a single level for example, development activities, or work processes, or organizational activities.
Incremental change	Gradual and stepwise adaptation of one or several system components as a response to a gap.
Information system	An organizational (sub) system that consists of technical, organizational, and semiotic elements that is capable of information processing.
Information system development	A process that creates and re-configures socio-technical elements and their relationships within and between: (1) signs and symbols deployed; (2) organizational tasks, structures, and processes, and (3) its technological core.
Intervention/event	A planned measure taken towards one or more socio-technical elements, or a system as a whole at some system level as to mitigate against or remove an observed gap.
Multi-level explanation of change	Change accounts that are not limited to horizontal explanations by solely examining interactions among current elements at a single level of a well-bounded system. Explaining punctuated ISD change requires to observe differences between incremental change and deep structure transformations.
Organizational context	Immediate organizational environment of the building system that cover the resource, authority, culture, political systems in which the IS change unfolds.
Patterns	A set of consecutive socio-technical system states that have a regular form across time or across systems. If such consecutive states can be explained by causal causes the patterns follow causal laws. In other regular cases the patterns are chaotic. If no patterns are observed the system behavior is random.
Punctuated change model	IS change can be characterized by alternations between longer periods of incremental adaptation – called first-order change – and briefer periods of revolutionary upheaval of episodic change – called second-order change.
Socio-technical system	Any organizational system viewed as a multivariate system consisting of four interacting and aligned components – task, structure, actor, and technology.
Socio-technical system state	The properties of socio-technical components and their systemic relationships in a given socio-technical system at any point of time.
Stability	Stability consists of maintaining and carrying out these choices made with regard to a deep structure where the elements are aligned to the extent that the deep structure prevails.
S–T System stability	A state of a socio-technical system where the four components are aligned and the system is balanced in that the system responses or its performance is not deteriorated.
S–T System instability	A state of a socio-technical system where the four components are not aligned and the system is unbalanced in that the system responses are not predictable or its performance is deteriorated.
S–T Punctuation	Socio-technical elements and their interactions are re-configured so that the system exhibits a totally new range of responses and thus exhibits new emergent properties.
System history	A set of events that have produced and precede the current system state at a given system level.
System upheaval	A change that dismantles the current deep structure and reforms a new deep structure.
Vertical analysis	A process of unpacking interdependencies between two consecutive system levels as to explain IS change.
Work system	Socio-technical system that executes, coordinates, and manages information-related work activities.