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Uncertainty and the consequences of technological innovation

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ABSTRACT
Technological innovation is frequently a means for reducing uncertainty in organizational activities. At the same time, uncertainty also arises about the potential consequences of introducing the innovation. Innovation involving complex new information systems (IS) often carries uncertainty about consequences, particularly when goals or expectations are unclear. Previous research has reinforced the significance of the problem whereby anticipated consequences have less impact, no impact or the opposite impact to that anticipated. Unanticipated consequences, particularly when also undesirable, emerge to frustrate organizations’ innovation efforts. A process research framework is proposed for examining the linkages between uncertainty and consequences. The contribution of this paper is an explanation of theory and method for developing a model linking the management of uncertainty to knowledge of consequences. A case study in an Australian healthcare organization and the case methodology are described. The research is work in progress in the organization, tracking through nine months of implementation period and three months of routine use.

Keywords
Technological Innovation, Implementation, Uncertainty, Consequences, Impacts, Process Research.

INTRODUCTION
Technological innovation offers new solutions to existing problems, and new alternatives to choose from in meeting an organization’s goals. However, this novelty is accompanied by uncertainty. Uncertainty is defined here as the existence of incomplete, unreliable or inconsistent information on goals, alternatives and consequences of an action. The paper focuses on the actions of implementing and using information systems (IS) innovation in organizations, and narrows discussion to uncertainty about consequences of introducing the innovation. Uncertainty is a central issue in technological innovation, and it is argued that a better understanding of the processes linking uncertainty to consequences can benefit organizations seeking to introduce complex new IS.

Preparing for the use of new technology in an organization has received significant attention in the innovation literature, with several processes giving rise to uncertainty clearly identified. Central among these are adaptation between the technology and the organization (Leonard-Barton 1988; Rogers 2003) and barriers during organizational learning (Attewell 1992; Cohen and Levinthal 1990; Fichman and Kemerer 1997). Complexity associated with the innovation (Gerwin 1988; Rogers 2003), the organizational environment (Nord and Tucker 1987; Scudder, Schroeder, Van de Ven, Seller and Wiseman 1989) and the implementation process itself (Tornatzky and Fleischer 1990; Van de Ven, Polley, Garud and Venkataraman 1999), have also been investigated as causes of uncertainty in technological innovation.

CONSEQUENCES OF INNOVATION
The organizational consequences of technological innovation (including but not limited to information systems) have received comparatively little attention in the literature. Rogers (2003) identified three issues contributing to this lack of attention: (1) researchers tacitly assume that all consequences will be positive, (2) typical survey research methods are less appropriate for studying consequences because extended observations over time are required, and (3) consequences are
difficult to measure because users may not be fully aware of them. Rogers (2003) also distinguished three aspects of innovation consequences: whether they are anticipated or unanticipated, desirable or undesirable, and direct or indirect.

Research that does exist on consequences of technological innovation has highlighted conflicting empirical findings (Markus and Robey 1988; Robey and Boudreau 2000) making it difficult to draw meaningful conclusions. In some cases the innovation had the anticipated organizational consequences, in others it did not have the anticipated consequences due to implementation failure, in yet others implementation succeeded but the anticipated consequences did not materialize, or worse, were opposite to those predicted. Cases were also reported where innovations produced consequences that were totally unanticipated. Summarizing this landscape, Robey and Boudreau (2000) recommend that future research on consequences of technological innovation (1) use process theory, (2) employ different theoretical logic and (3) adopt a multi-level perspective.

Consequences are defined in this paper as any change that occurs to an individual or organizational system resulting from implementation of an innovation. This paper contends that consequences emerge not only after implementation is complete and use of the innovation has commenced, but also during implementation. This was an important consideration in developing the research framework, discussed below. For example, in a case study for this research it was realized during implementation that consumers of the innovation (a state-wide electronic health record) would need to be pre-subscribed because to subscribe people manually from a population of four million after implementation would be prohibitive in time and cost. A consequence is that consumers’ choice in using this innovation will be not to participate rather than to participate. This is a significant consequence for the organization and millions of affected users, requiring changes to health information systems privacy laws, and it emerged before use commenced.

This paper argues that more sense can be made of consequences emerging from IS innovation by studying the dynamic linkages between uncertainty and consequences as anticipated consequences resolve (or do not) into actual consequences over time, and unanticipated consequences emerge. A process research framework employing the theoretical logic of life-cycles and teleology (goal-seeking) will be used to guide the interpretation of research data. The logic of cycles and teleology is suitable for describing activity at multiple levels of analysis, the primary levels in this research being individual, organizational and inter-organizational. It is explicitly acknowledged through the typology used that not all consequences are positive, and that unanticipated and undesirable consequences are of particular concern to IS practitioners.

LINKING UNCERTAINTY AND CONSEQUENCES

Uncertainty was defined above as incomplete, unreliable or inconsistent information about the goals, alternatives or consequences of an action. Therefore it is necessary to examine the causes of incompleteness, unreliability and inconsistency in information about consequences of IS innovation.

Incompleteness - Learning barriers arising in the pursuit of understanding an innovation’s consequences are a source of incompleteness of information. Learning barriers to understanding consequences can be caused when supply-side and mediating organizations have not developed a sufficient stock of experience (Attewell 1992) and the burden of doing so falls onto the innovating organization.

Inconsistency - There is evidence that the process of technology-organization adaptation during implementation is generally dynamic and unpredictable (Leonard-Barton 1988) rather than deterministic. There is a potential for inconsistent information from sources with different experiences, even if the innovation and other pre-conditions were comparable.

Unreliability - Unreliability of information about consequences can emerge when the information available is too complex to be fully understood. High levels of complexity in the innovation itself, the organizational environment and implementation process are all potential sources of unreliable information about consequences.

Gerwin (1988) developed an innovation process model for the adoption and implementation of an innovative IS for manufacturing process control systems. He identified three types of uncertainty: technical, financial and social. Gerwin (1988) argued that technical complexity and product recency increase technical and financial uncertainty in adoption, infrastructure preparation and implementation processes. The combined effect of complexity and an insufficiently sophisticated infrastructure contribute to social uncertainty about expectations and performance measure for the innovation. By tracking uncertainty through several stages of the innovation process, the model suggests that uncertainty can accumulate over time to influence outcomes. However, the research offered no direct empirical support for the model. The model also stopped short of consequences, ending instead with the ‘chances of successful implementation’.

Potential effects of uncertainty on consequences are now briefly discussed. First, uncertainty affects our understanding of dependencies between desirable and undesirable consequences, and even awareness of such dependencies (Rogers 2003).
Second, uncertainty about anticipated consequences motivates information seeking (Rogers 2003) and organizational learning (Attewell 1992). For complex IS innovations, efforts to reduce uncertainty may encounter knowledge barriers, which resist these efforts. Third, unanticipated consequences derive from a lack of understanding about the innovation and the social system in which it is used (Rogers 2003). No information about uncertainty in relation to directness or indirectness of consequences was identified in previous literature.

RESEARCH FRAMEWORK

Researchers have criticized past approaches comprising only dependent and independent variables as being inadequate for studying consequences of technological innovation where change over time is a key dimension of study (DeSanctis and Poole 1994; Robey, et al. 2000; Rogers 2003). The framework proposed in Figure 1 begins with previously identified antecedents of uncertainty, but seeks to deepen our understanding of uncertainty and its linkages to perceived consequences both during and after implementation, using empirical data collected with a process research method. The data is being collected during and after the implementation of a complex IS innovation in the Australian healthcare system.

Figure 1: Research framework

Following the recommendations of Robey and Boudreau (2000), the research framework replaces causal relationships between independent variables related to uncertainty, and the dependent variables of innovation consequences with a process model that allows for multiple explanations of change and multiple levels of analysis. The process model seeks to empirically examine the time-ordered sequence of events in a case study organization as it implements, and then uses, an IS innovation. Figure 2 presents an illustrative view of the phenomenon being investigated. A detailed process model of the mechanisms at work, while being a primary goal of the research program, is yet to be developed from empirical data.
Figure 2: Illustrative representation of the phenomenon

Figure 2 illustrates anticipated and unanticipated consequences being progressively realized over the course of implementation and use for two scenarios ‘S1’ (dotted line) and ‘S2’ (dashed line). Realization of consequences begins at implementation and progresses through commencement of use. Scenario S1 shows realization of more anticipated consequences and fewer unanticipated consequences - related to effective uncertainty responses by the organization through the linkages described earlier. At time t+n, some consequences have not been, and may never be realized.

CASE STUDY

A case study is being conducted in a large Australian healthcare organization. The IS innovation being implemented is the electronic health record. The electronic health record is a longitudinal collection of personal health information, usually based on an individual, entered or accepted by healthcare providers, that can then be distributed over a number of sites or aggregated at a particular point. The information must be organized to support continuing, efficient and quality healthcare. It must be under the control of the individual and stored and transmitted securely.

For the Australian health sector, this is an innovation involving significant uncertainty, and effective navigation of the consequences of this innovation is highly valued. The project needs to coordinate with related initiatives by other stakeholders in public and private sector healthcare, and the integration of many sources of information by providers such as GPs, hospitals and specialists. Data collection for the research began in February 2005, with implementation of a pilot project due in October 2005. The pilot will be formally evaluated in December 2005.

CASE METHODOLOGY

A methodology for investigating process phenomena in technological innovation (Van de Ven and Rogers 1988) has been adopted in this research. The framework elaborates four key steps necessary for effective execution of a process research methodology:

(1) A clear set of concepts

Uncertainty, the independent construct, is being tracked in relation to potential causes: mutual adaptation, learning barriers, and complexity; types: incompleteness, unreliability, and inconsistency; and context: technical, financial or social. Consequences, the dependent construct, is being studied in relation to the categories of anticipated/unanticipated, desirable/undesirable and direct/indirect, and the level of analysis: individual, organization and inter-organizational. The case-specific concepts are organized into five general concepts: ideas, people, transactions, context, and outcomes (Van de Ven, Angle and Scott Poole 1989). Prior research has identified these five general concepts as central concerns to managers in directing innovations (Van de Ven 1986). This organization also creates potential for comparisons with numerous previous cases, such as the 14 studies reported in (Van de Ven, et al. 1989).

(2) Systematic observation methods

Both regular and intermittent site observations are being made over time about how uncertainty develops and is managed during implementation and initial use of the innovation. The researcher spends regularly scheduled time at the organization.

(3) Representing the data

Process research involves tracking changes in a number of concepts over time. These are represented as sequential ‘events’ in a database. An event is a coded observation of some change observed in one of the concepts being studied. For example, an event consisting of a ‘transaction’ to add a ‘person’ to the implementation team to overcome a ‘learning barrier’ and rectify ‘incompleteness’ of information about a standard for systems interoperability might be recorded. This could be viewed as an uncertainty-reducing event and traced through future events to one or more consequences.

(4) A theory to make sense of the data

The theory being used offers alternative explanations to the theories underlying deterministic models of innovation. Poole et al. (2000) described four alternative theories of development and change in organizations. The explanation of change adopted
for this research brings together two of these theories - life cycle and teleology - in a form resembling Leonard-Barton’s (1988) theory of converging mutual adaptation cycles between technology and organization.

CONCLUSION
This research answers the call to place more emphasis on our understanding the consequences of IS innovation. It is acutely recognized that not all consequences of IS innovation are positive or anticipated. Uncertainty and consequences have been clearly defined and conceptualized to improve our understanding of linkages between sources, types and the context of uncertainty and different aspects of consequences. The research seeks to provide organizations with patterns of behavior for responding effectively to uncertainty about consequences of IS innovation through the development of a process model. It involves extended observations over time to analyze the sequence of events that unfold, informed by a process theory of change.

REFERENCES