

TECHNOLOGY ADOPTION IN COMPLEX SYSTEMS

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Abstract

Adoption of information technology remains an important consideration in IS research. With the growing number of complex systems being implemented within the organizations, there also exists a need to understand these systems, their adoption and post adoption behavior. This study focuses on these issues. We develop a description of complex technologies. Subsequently we extended the technology acceptance model to include perceived risk of use, as a new construct in the nomological network leading to, post-adoptive exploration of complex technologies.

Introduction

Information technology adoption and its use in organizations remains a central concern for IS research and practice. The release of the 10 year update of the DeLone and McLean IS success model, reaffirms the importance of IS usage as an important mediator to performance (DeLone & McLean, 2003). As a result, a lot of studies have focused on better understanding of the determinants of technology acceptance and usage. (see Venkatesh, Morris, Davis, & Davis, 2002 for a review).

Significant progress has been made in this domain. In particular, significant, theoretical and empirical support has been accumulated in support of the Technology Acceptance Model (TAM) (Davis, 1989) as a parsimonious explanation of the phenomenon. TAM theorizes that an individual's behavior intention to use a system is determined by two beliefs: perceived usefulness, defined as the extent to which a person believes that using the system will enhance his or her job performance, and perceived ease of use, defined as the extent to which the person believes that using the system will be free of effort.

Two significant directions for future research emerge in technology acceptance. Firstly, much research has focused on adoption and usage behaviors. Relatively little attention has been given to post-adoptive behaviors such as exploratory post-adoptive use (Nambisan, Agarwal, & Tanniru, 1999). Given that much organizational benefit can derive from new and innovative uses of extant technology, the understanding of the factors, which enable such post-adoptive behaviors, becomes a fruitful endeavor for research.

Secondly, much research on technology acceptance focused on relatively "simple" personal systems like windows (Karahanna, Straub, & Chervany, 1999), Email (Davis, 1989; Davis, Bagozzi, & Warshaw, 1989), Spreadsheets (Mathieson, 1991; Venkatesh & Davis, 1996), Word-processing software (Doll, Hendrickson, & Deng, 1998; Venkatesh & Davis, 1996), Voice mail (Chin & Todd, 1995; Straub, Limayem, & Karahanna, 1995), Simple DBMS (Doll et al., 1998; Szajna, 1994), WWW (Lin & Lu, 2000), and Expert systems (Gefen & Straub, 1997). Acceptance of complex organization-wide systems, however, typically entails higher knowledge barriers and higher interdependency of use. As such, additional factors may gain salience in explaining their adoption, use, and infusion within an organization.

From a theoretical point of view, it is important to investigate antecedents of adoptive and post-adoptive behaviors of organization's wide complex technologies and how these differ from adoptive and post-adoptive behaviors of simple technologies (Melone, 1990). From a practical point of view, as organizations are making significant investments in complex organization's wide technologies such as ERP systems, Data Warehousing infrastructures and tools, and CRM applications, understanding of the factors that promote greater and more innovative usage of these systems will likely yield increased organizational value.

An important distinction between simple and complex systems is the extent of discretionary behavior in the initial adoption. While adoption of simple systems can be either voluntary or mandatory, adoption by individual users of organization-wide complex systems such as ERPs is typically mandatory. Thus, it is possible for individuals to adopt organization-wide complex systems even if their attitudes towards adoption are not favorable. Thus, the usage of such systems is mandated, attention shifts to the nature of post-adoptive usage as a key to exploiting the benefits of the technology.

In an effort to gain an enhanced understanding of the phenomenon, this paper focuses on the role of perceived risk of use as an important antecedent of post adoptive behaviors of complex organization-wide systems. We focus on perceived risk of use as a key construct in post-adoptive exploratory usage of complex systems for two reasons: First, complex systems typically entail higher levels of use interdependencies, and second, they entail higher knowledge barriers in understanding cause-effect relationships embedded within the system.

The paper proceeds as follows: In the next section we develop a description of complex technologies. Section III extends the technology acceptance model, to include perceived risk of use as a new construct in the nomological network, leading to post-adoptive exploration of complex technologies. The last section describes the proposed research methodology to test the research model of the study.

Complex Systems

Since the focus of the study is exploratory usage of organization-wide complex systems (OWCS), it is necessary to provide a description of what constitutes a complex system. A review of the literature reveals no commonly accepted definition of complexity. In fact, complexity is presented as a multifaceted construct with more than seventy definitions of the concept used in diverse areas (Bar-Yam, 1997). Since our interest is complex systems, we focus our discussion on descriptions of complexity as they apply to defining complex systems.

Complexity has both an objective as well as a socially constructed component (Flood & Carson, 1993). From an objective perspective, a complex system is usually constituted of many interacting elements. The complexity of the system is proportional to the number of elements, the number of interactions in the system, and the complexities of the elements and of their interactions (Schneberger, 1995). From a subjective perspective, the focus is on individuals' perceptions of the system's underlying complexity. Thus, taking both into consideration, Yates (1978) defines information technology complexity by *the number and variety of components, the number and strength of interactions, their combined rate of change, and individuals' perceptions of difficulty in understanding the technology*. This is the definition that we will adopt in the current study.

Thus, Yates definition includes four distinct components of complexity: (a) number and variety of components, (b) number and strength of interactions, (c) combined rate of change, and (d) difficulty in understanding the technology. The first three overlap with Wood's (1986) conceptualization of complexity along with the dimensions of component complexity, coordinative complexity, and dynamic complexity (see Wood's definitions in Table 1). The fourth refers to an understanding of the know-how of the technology (i.e., understanding the cause-effect relationships embedded within the technology). Barriers to acquire such knowledge lead to difficulty in understanding the causal implications of interactions with the system (Nambisan et al., 1999). We elaborate on each one below (Table 1) and provide examples within an ERP context.

Though it is important to understand the concept of complex systems, theories in social psychology (on which TAM is based) as well as theories of innovation diffusion (e.g., Rogers, 1995) stipulate that it is the individual's perception of technology characteristics that impacts the technology acceptance decisions and not necessarily the objective (or primary) characteristics of the technology (Bandura, 1986; Rogers, 1995; Venkatesh et al., 2002). Based on this premise, and to identify how complexity may impact system acceptance, in the following section we use the dimensions of "objective" and subjective complexity discussed above to develop a new construct called Perceived risk of use. This construct, which is grounded in the definition of complexity, is then situated within the nomological network leading to post-adoptive exploratory use of the technology.

Table 1. Dimensions of Complex systems

Type of Complexity	Definition	OWCS implication	ERP Example
Component Complexity	Direct function of the number of	Number of distinct components of a	Number of modules in an Enterprise

	distinct acts that need to be executed in the performance of the task and the number of distinct information cues that must be processed in the performance of those acts	system	resource planning software
Coordinative Complexity	Coordinative complexity refers to the nature of relationships between task inputs and outputs?	Extent of Interdependence between the various components of the system	Effect of wrong use of a data field during order entry on decisions based on data mining
Dynamic Complexity	Changes in the states of the world which have an affect on the relationships between inputs and outputs	Extent of changes in the relationships between inputs and outputs due to the openness of the system	Changes in meaning of item master because of changes in environment

Perceived risk of use

As defined by Longmans dictionary, risk is “to put something in a situation in which it can be lost, destroyed or harmed”. Since Bauer (1960) formally proposed consumer behavior as a risk taking activity, perceived risk has generated considerable interest in the literature. More recently the concept of risk has been brought into the MIS literature, mainly in the context of online transactions (Hoffman, Novak, & Peralta, 1999; Jarvenpaa & Tractinsky, 1999; Swaminathan, Lepkowska-White, & Rao, 1999). Literature review suggests that there is no universally accepted conceptual definition of risk, though most of the definitions refer to uncertainty relating to consequences of engaging in a behavior and particularly to the danger of adverse consequences. Thus, this research adapts Jarvenpaa & Trachinski’s (1999) definition of perceived risk to the context of the study. We define perceived risk of use (PRU) as *a user’s perceptions of the uncertainty and extent of adverse consequences of engaging in system use or exploration*.

Ring & Van de Ven (1994) classify risk into behavioral risk and technology risk. Technology risk is risk arising from the technology infrastructure itself. In the context of complex system exploratory usage, we content that perceptions of technology risk will largely emanate from the complexity inherent in the technology. In turn, technology risk would influence behavioral risk and would be reflected through it (Poole & DeSanctis, 2003). Thus, perceptions of behavioral risk will be rooted in the underlying complexity of the technology and in the implications of such complexity to use much like subjective complexity, which is rooted in the underlying objective complexity of the system.

The literature further argues two important points. First, it substantiates our conceptualization of a casual relationship between perceived risk and behavioral intention (post-adoptive behavior) as shown in Figure 1. Second, it points to the fact that perceived risk is a multi-dimensional construct and these dimensions are dependent on properties of the underlying system.

The focus of our study is on perceived risk of use in the context of organization-wide complex systems. As such, based on the definitions of system complexity in the literature, four distinct dimensions of perceived risk of use emerge:

- (a) Reversibility (Bandura, 1986) defined as the extent to which an action performed through the system can be quickly and easily reversed.
- (b) Exposure (Stewart) defined as the extent to which an individual’s action can lead to potentially serious visible consequences and the amount of time before a mistake or a poor decision can be discovered.

- (c) Interpretive Difficulty defined as perceived difficulty in interpreting the cause-effect relationships embodied within the technology, and
- (d) Adverse consequence uncertainty defined as the extent of perceived damage that would be done if the consequences of the act did not prove to be favorable.

Below we expand on each one of these dimensions (see Table 2).

Reversibility

Reversibility refers to the extent to which an action performed through the system can be quickly and easily reversed. Thus, reversibility refers to the ease of correcting an error. The easier it is to correct an error made while using or exploring new uses of the system, the lesser the perceived risk of such behavior since the adverse consequences of engaging in such behavior are largely alleviated (Derbaix, 1983; Jarvenpaa & Tractinsky, 1999; Taylor, 1974).

Interdependent events set up a sequence of actions based on an initial action. The greater the coordinative complexity, the higher the dependence of subsequent actions based on the initial action. Thus, reversibility of action in such a situation would mean reversing the action as well as its impact on all subsequent actions.

Exposure

Exposure is the extent to which an individual's action can lead to visible consequences and the amount of time before a mistake or a poor decision can be discovered (Stewart). There is more exposure when actions have immediate highly visible consequences for the organization, and mistakes or poor judgments are widespread visible across individuals and units in the organization. There is less exposure when there is a long delay before the consequences become visible and when those consequences are highly localized.

Actions taken in complex systems not only have real time impact, but the inherent interdependencies also imply a wider, more visible impact on organizational resources. Individual actions within such systems are seen across the organization and can affect organization's wide resources. For example, a inputting a wrong production schedule can have visible, immediate impact across the supply chain, from raw materials ordered to forecasted quantity available for sale.

Interpretive Difficulty

Based on the above framework of system complexity, system complexity increases as the number of components, the amount of coordination between the components and the changes in the relationships between them increase i.e. increase in any of the above complexities. As these objective aspects of system complexity increase, an individual's perceptions of difficulty in understanding the system, or knowledge barriers, increases.

Interpretive difficulty is thus the extent to which the individual perceives these knowledge barriers (Attewell, 1992). Defined more formally, interpretive difficulty is the perceived difficulty in interpreting the cause-effect relationships embodied within the technology. For example, because of the high data and process integration in ERPs, changes in any part of the system ripple through and affect a number of other processes and outputs. Even though individuals understand these interdependencies in general, understanding the exact and complete cause-effect relationships implied by these systems becomes increasingly challenging and elusive.

Uncertainty of Adverse consequence

Whereas interpretive difficulty is more concerned with understanding the system-wide implications of one's actions, uncertainty of adverse consequences focuses on whether or not one's exploration of the system is likely to have unintended and harmful consequences for the individual and well as the organization. Adverse consequence uncertainty is the extent of perceived damage that would be done if the consequences of the act did not prove to be favorable (Derbaix, 1983). Thus, it refers to the possibility of making mistakes while exploring the system, the severity of those mistakes to the organization, and the severity of retributions as a result of these mistakes (e.g., loss of job). The probability and severity of mistakes are influenced by the underlying complexity of the system. The more component, coordinative, and dynamically complex the system, the more likely for individuals to make mistakes that have serious consequences. The latter is influenced by the degree of reversibility and exposure of the action as well as the organizational culture and norms.

Table 2. Summary of risk dimensions and their link to complexity dimensions

Perceived risk dimension	Definition	Technology underlying risk attribute
Exposure	Exposure is the extent to which an individual's action is visible and the amount of time before a mistake or a poor decision can be discovered	Component Complexity – Coordinative complexity
Reversibility	Reversibility refers to the extent to which an action performed through the system can be quickly and easily reversed.	Coordinative complexity
Interpretive difficulty	Perceived difficulty in interpreting the cause-effect relationships embodied within the technology	Component Complexity Coordinative complexity Dynamic complexity
Uncertainty of adverse outcomes	Uncertainty of the consequences of making mistake represents the extent of damage that would be done if the consequences of the act did not prove to be favorable	Component Complexity Coordinative complexity Dynamic complexity

Table 2 summarizes the four dimensions of perceived risk of use, i.e. exposure, reversibility, interpretive difficulty, and adverse outcome uncertainty, and the underlying technological risk component(s).

RESEARCH MODEL

Focusing on post-adoptive behaviors, the research model extends TAM to include Perceived Risk of Use (PRU). Perceived risk of use is hypothesized to affect behavioral intention to explore a system both directly and via perceived usefulness. Below we only posit hypotheses that include perceived risk of use. Even though formal hypotheses are not proposed, given the considerable empirical evidence accumulated, we expect the TAM relationships to hold in the current context. Figure 1 shows the research model of the study.

Even though organizations invest millions in complex systems such as ERPs, only a fraction of the system functionality is employed. Encouraging users to explore new and innovative uses of such systems is of paramount importance in deriving increased return from these investments. Thus, the current research focuses on intentions to explore as the post-adoptive behavior of interest. Intentions to explore (Nambisan et al., 1999) refer to one's intention to find such new uses of the technology by exploring additional features of the technology or by using "old" features in new ways. As such, it represents a behavior that individuals engage in of their own accord and it is typically not mandated by organizational edict.

We posit that, in addition to perceived ease of use and perceived usefulness (whose relationships to behavioral intention to use are well-established in the literature), perceived risk of use will also impact exploratory use intentions. The higher the perceived risk of use embodied within the technology (due to its higher interpretive difficulty, exposure, probability of adverse consequences, and irreversibility of mistakes), the less likely the user to engage in exploratory use behaviors. This relationship between these two can be explained through prospect theory (Kahneman & Tversky, 1979). Germinating out of economics, this theory presents a model of decision making under risk. The basic tenant of the theory states that people under weigh outcomes that is merely probable in comparison with outcomes that are obtained with certainty. This tendency, called the certainty effect, contributes to risk aversion by selecting choices involving sure gains (Bhimani, 1996; Hoffman et al., 1999; Ratnasingham, 1998; Swaminathan et al., 1999; Tan & Teo, 2000). Thus, we posit:

H1: Perceived risk of use will have a negative effect on intentions to explore a complex system behavior intention

Literature of TAM has shown a significant relationship between perceived ease of use and perceived usefulness. Similarly, we posit a relationship between perceived risk of use and perceived usefulness. Perceived usefulness represents an implicit tradeoff or pros and cons of engaging in a behavior. A system cannot be found useful if the perceived costs of engaging in the behavior outweigh the perceived benefits. The more risky the behavior, the more cons will be perceived, and therefore, the lower its usefulness:

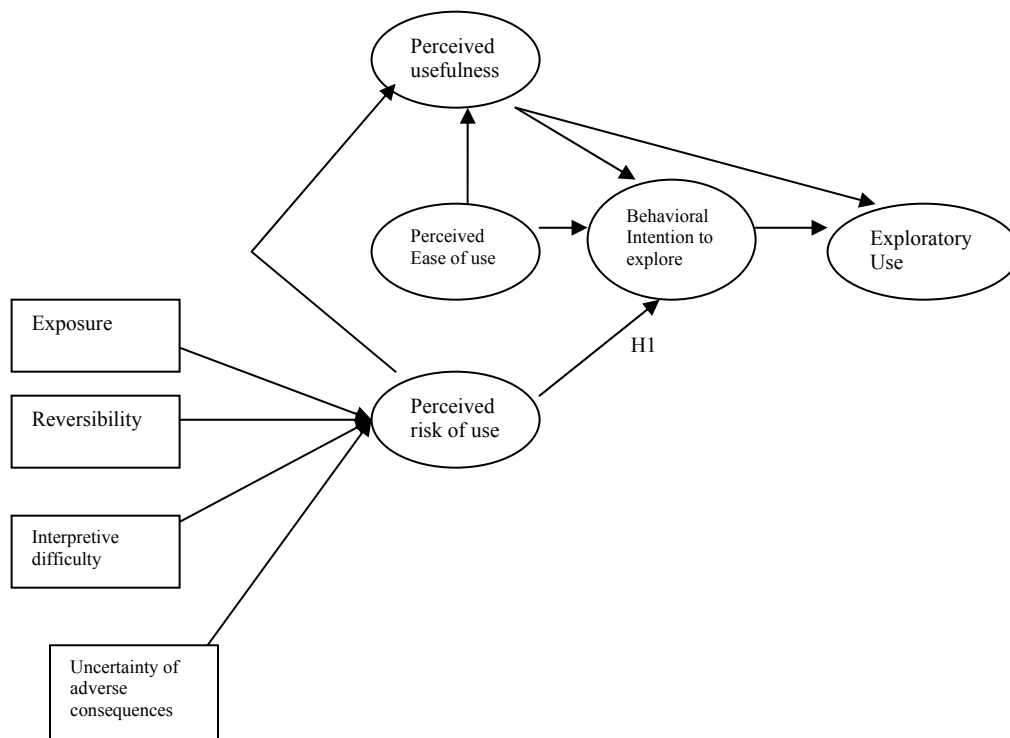
H2: Perceived risk of use will have a negative effect on the perceived usefulness of post-adoption exploration behavior intention

Research method

After the scale for measuring perceived risk of use has been constructed using the instrument development methodology described by (Moore & Benbasat, 1997), the instrument will be pilot tested in an ERP class of MIS seniors. Their adoption of the system and basic use, like in an organization, is mandatory. The main data collection will consist of a field study of ERP users within an organization.

The psychometric properties of our scales as well as the theoretical model will be analyzed using structural equation modeling and, specifically, PLS.

Figure 1. Research model



References

- Attewell, P. (1992). Technology Diffusion and Organizational Learning - the Case of Business Computing. *Organization Science*, 3(1), 1-19.
- Bandura, A. (1986). *Social foundations of thought and action : a social cognitive theory*. Englewood Cliffs, N.J.: Prentice-Hall.
- Bar-Yam, Y. (1997). *Dynamics of Complex Systems*: Addison-Wesley.
- Bauer, R. (1960, December). *Consumer Behavior as Risk Taking*. Paper presented at the National Conference of the American Marketing Association,.

- Bhimani, A. (1996). Securing the Commercial Internet. *Communications of ACM*, 39(6), 29-35.
- Chin, W. W., & Todd, P. A. (1995). On the Use, Usefulness, and Ease of Use of structural equation modeling in MIS research: A Note of Caution. *MIS Quarterly*, 19(2), 309-334.
- Davis, F. D. (1989). Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quarterly*, 13(3), 319-339.
- Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User Acceptance of Computer-Technology - a Comparison of Two Theoretical-Models. *Management Science*, 35(8), 982-1003.
- DeLone, W. H., & McLean, E. C. (2003). The DeLone and McLean Model of Information Systems Success: A Ten-Year Update. *Journal of Management Information Systems*, 19(4), 9-30.
- Derbaix, C. (1983). Perceived risk and risk relievers. *Journal of Economic Psychology*, 3(1), 19-38.
- Doll, W. J., Hendrickson, A., & Deng, X. (1998). Using Davis's Perceived Usefulness and Ease-of-Use instruments for decision making: A Confirmatory and Multigroup Invariance Analysis. *Decision Sciences*, 29(4), 839-869.
- Flood, R. L., & Carson, E. R. (1993). *Dealing with complexity : an introduction to the theory and application of systems science* (2nd ed.). New York: Plenum Press.
- Gefen, D., & Straub, D. (1997). Gender difference in the perception and use of e-mail: An extension of the technology acceptance model. *MIS Quarterly*, 21(4), 389-400.
- Hoffman, D. L., Novak, T. P., & Peralta, M. (1999). Building Consumer Trust Online. *Communications of ACM*, 42(4), 80-85.
- Jarvenpaa, S. L., & Tractinsky, N. (1999). Consumer Trust in an Internet Store: A Cross-Cultural Validation. *Journal of Computer-Mediated Communication*, 5(2).
- Kahneman, D., & Tversky, A. (1979). Prospect Theory: An Analysis of Decision under Risk. *Econometrica*, 47(2), 263-292.
- Karahanna, E., Straub, D. W., & Chervany, N. L. (1999). Information Technology Adoption Across Time: A Cross-Sectional Comparison of Pre-Adoption and Post-Adoption Beliefs. *MIS Quarterly*, 23(2).
- Lin, J. C. C., & Lu, H. (2000). Towards an Understanding of Behavioral Intention to Use a Web Site. *International Journal of Information Management*, 20(3), 197-208.
- Mathieson, K. (1991). Predicting User Intentions: Comparing the Technology Acceptance Model with the Theory of Planned Behavior. *Information Systems Research*, 2(3), 173-191.
- Melone, N. P. (1990). A Theoretical assessment of the user-satisfaction construct in information systems research. *Management Science*, 36(1), 76-91.
- Moore, G. C., & Benbasat, I. (1997). Development of an Instrument to Measure the Perceptions of Adopting an Information Technology Innovation. *Information Systems Research*, 2(3), 192-222.
- Nambisan, S., Agarwal, R., & Tanniru, M. (1999). Organizational mechanisms for enhancing user innovativeness in information technology. *MIS Quarterly*, 23(3), 365-395.
- Poole, M. S., & DeSanctis, G. (2003). Structuration theory in information systems research: Methods and Controversies. In M. E. Whitman & A. B. Wozzczyński (Eds.), *The handbook of information systems research*. Hershey, PA: Idea Group Pub.
- Ratnasingham, P. (1998). The importance of trust in electronic commerce. *Internet Research*, 8(4), 313-321.
- Ring, P. S., & Van de Ven, A. H. (1994). Developmental processes of cooperative interorganizational relationships. *Academy of Management review*, 19(1), 90-119.
- Rogers, E. M. (1995). *Diffusion of innovations* (4th ed.). New York: Free Press.
- Schneberger, S. L. (1995). *Distributed Computer System Complexity Versus Component Simplicity: Their Effects on Software Maintenance*. Paper presented at the International Conference on Information Systems, Hans Oppelland.
- Stewart, T. A. Trust Me on This. In W. Bennis, G. M. Spreitzer & T. G. Cummings (Eds.), *The Future of Leadership: Today's Top leadership thinkers speak to Tomorrow's Leaders* (pp. 67-77). San Francisco: Jossey Bass.

- Straub, D., Limayem, M., & Karahana, E. (1995). Measuring System Usage: Implications for IS Theory Testing. *Management Science*, 41(8), 1328-1342.
- Swaminathan, V., Lepkowska-White, E., & Rao, B. P. (1999). Browsers or Buyers in Cyberspace? An Investigation of Factors Influencing Electronic Exchange. *Journal of Computer-Mediated Communication*, 5(2).
- Szajna, B. (1994). Software Evaluation and Choice: Predictive Validation of Technology Acceptance Instrument. *MIS Quarterly*, 18(3), 319-324.
- Tan, M., & Teo, T. S. H. (2000). Factors Influencing the Adoption of Internet Banking. *Journal of Association for Information Systems*, 1(5), 1-42.
- Taylor, J. W. (1974). The Role of Risk in Consumer Behavior. *Journal of Marketing*, 38(2), 54-63.
- Venkatesh, V., & Davis, F. D. (1996). A Model for Antecedents of Perceived Ease of Use: Development and Test. *Decision Sciences*, 17(3), 451-481.
- Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2002). User acceptance of information technology: Toward a unified view. *MIS Quarterly*, 27(3), 425-478.
- Yates, F. E. (1978). Complexity and the limits to knowledge. *American Journal of Physiology*, 235, R201-R204.