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Understanding the dynamics of information system use

Abstract

User behavior in information systems (IS) has traditionally been modeled based on well-accepted behavioral theories like the theory of reasoned action (TRA), technology acceptance model (TAM) and the theory of planned behavior (TPB). A major limitation of this approach is its dependence on a snapshot view to capture the relationships between the variables at any given time. Research has shown that such relationships change over time (Szajna, 1996). The twin objectives of this study are to firstly, identify the limitations of the current approaches to model IS use and, secondly, to demonstrate the theoretical utility of understanding user behavior by incorporating feedback loops into such models. This study captures the dynamics of user behavior by employing system dynamics modeling. We have extended traditional hypotheses associated with user behavior into a dynamic hypothesis by incorporating feedbacks. Specific feedbacks lead from IS use to perceived ease of use and from productivity to IS-related work. We have tested the model under different scenarios. The managerial implication of this work is a better understanding of user behavior because these models have been able to demonstrate archetypal IS use patterns. Using such models managers can analyze different usage scenarios *before* making system changes or introducing new systems. The theoretical contribution of this study is the identification of archetypal user behavior by linking productivity with IS use.

Keywords: Information system (IS) use, system dynamics, archetypes

1. Introduction

Whenever a new or an updated or enhanced information system (IS) is introduced in an organization, its success is dependent upon how well it is accepted and subsequently used by individuals. The behavioral approach has traditionally allowed researchers to conceptualize and model “IS use” as a dependent variable. Behavioral models posit that user behavior is determined by a user’s attitude toward an information system. Intrinsic and extrinsic motivators, in turn, determine the attitude. Since such models do not explicitly link IS use to user productivity and tasks, this study forms a response to that gap.

In this study “productivity” has been linked to IS use and we have employed system dynamics as a research approach that complement the traditional research approach of adding independent variables in order to seek a “better” model. The approach taken in this study preserves the principle of parsimony associated with the Theory of Reasoned Action (TRA) (Fishbein and Ajzen, 1975) and its derivatives like the Technology Acceptance Model (TAM) (Davis, 1989) and Theory of Planned Behavior (TPB) (Ajzen 1985, 1991). Appendix A contains a detailed explanation of these theories. The idea is to recognize the direct and indirect influencers of IS use and, in doing so, incorporate feedbacks between IS use and other variables (like IT-enabled productivity and computer efficacy) in the research model.

This paper is organized as follows. We start by reviewing the literature on TAM. This literature review allows us to outline the essential strengths and contributions of TAM. We end this section by identifying major improvement opportunities while deploying TAM as a research model. The next section describes how we built the system dynamic model. We describe how we borrowed results from existing literature and incorporated those results to develop the dynamic hypothesis which is used to draw out and test the consequences of feedback loops between variables in the research model.. After presenting the results, we discuss the results by presenting a comparative analysis of results from four simulation runs. This section also compares and contrasts the simulation results with “typical” results from traditional research. We conclude the paper by highlighting the research contributions and future research directions.

2. Background

The most common and well-accepted frameworks for studying user behavior in information systems (IS use) have been the TRA, TAM, TPB and their derivatives and extensions. The common premise across these models is that IS use behavior is determined by an intention to use an information system – which, in turn, is determined by a user’s attitudes. Attitude is influenced by intrinsic and extrinsic influences (motivators). Figure 1 shows the technology acceptance model.

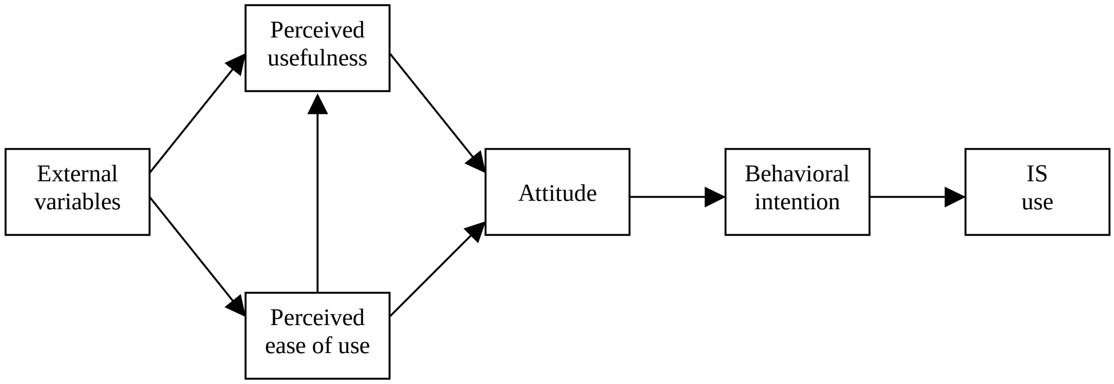


Figure 1. The technology acceptance model (Davis et al., 1989)

Over the years, many researchers have been attracted by the simplicity and explanatory power of such models. Consequently, they have used such models as their conceptual basis for studying IS use in different domains and contexts. In doing so, they have extended the model and added more variables to account either for variation not explained by the generic model or to attempt incremental improvements to the body of knowledge associated with IS use.

A researcher typically looks for significant path coefficients when testing such models. We present a sampling of recent research on IS use in Table 1 to summarize the diversity of domains studied and the nature of knowledge that such studies generate.

Study	Objective	Use context	Conclusions
Agarwal and Prasad (1999)	Test whether individual differences and IT acceptance is mediated by the constructs of the technology acceptance model	The basic functionality offered in the two environments (mainframe or minicomputer based and PC-based), for example, word processing, spreadsheets, graphics, etc., was quite similar. At the time of data collection users had not completely switched over to the new system	Results confirm the basic structure of the model, including the mediating role of beliefs. Results also identify several individual difference variables (individual's role with respect to technology, an individual's level of education, and prior, similar experiences) that have significant effects on TAM's beliefs.
Hu et al. (1999)	Examine the applicability of the Technology Acceptance Model in explaining physicians' decisions to accept telemedicine technology in the health-care context	Physicians practicing at public tertiary hospitals in Hong Kong	TAM was able to provide a reasonable depiction of physicians’ intention to use telemedicine technology. Perceived usefulness was found to be a significant determinant of attitude and intention but perceived ease of use was not.
Hong et al. (2001/2002)	Investigate the effect of a set of individual differences (computer self-efficacy and knowledge of search domain) and system characteristics (relevance, terminology, and screen design) on intention to use digital libraries	Students using the digital library in the Open University of Hong Kong (that maintains 1,000 electronic databases, various e-journals, dictionaries, handbooks, and encyclopedias, library catalogues of local and overseas higher education	Three system characteristics (relevance, terminology and screen design) have different effects on users' beliefs about the digital library. While relevance has a significant effect on both perceived ease of use and perceived usefulness of the digital library, the other two system characteristics, terminology and screen design, have significant effects only on

Study	Objective	Use context	Conclusions
		institutions, and special indices linking to 40 distance-learning organizations throughout the world.)	perceived ease of use.
Plouffe et al. (2000)	Test and compare sets of antecedent constructs drawn from both TAM and the Perceived Characteristics of Innovating (PCI) inventory.	A large-scale market trial of a smart card-based electronic payment system being evaluated by a group of retailers and merchants	The PCI set of antecedents explains substantially more variance than does TAM while also providing managers with more detailed information regarding the antecedents driving technology innovation adoption.
Al-Gahtani (2001)	Seek empirical support for the technology acceptance model in the UK	Students with one year of experience in heterogeneous organizations across the UK	The fundamental relationships and linkages among the TAM motivational constructs (attitude toward using, perceived usefulness and perceived ease of use) and the outcome construct (IT acceptance) tested in this study were in full agreement with prior research
Mathieson et al. (2001)	Test the extended TAM by considering the individual's perceptions of resource availability	The study examined volitional use of a bulletin board system (BBS) developed by the Institute for Management Accountants (IMA). The IMA is the principal professional organization for management accountants, with approximately 83,000 members world-wide in over 300 chapters.	Results support the extended TAM's contention that perceived resources affect an individual's intention to use an information system. The main contribution of the extended model is that it expands TAM's range.
Pijpers (2001)	Test a TAM-based research model to assess the factors that influence the use of IT by senior executives	An Executive Information System (EIS), was used as the IT tool under review. 87 senior executives drawn from 21 European-based multinationals were sampled.	The results supported the core TAM and found only a small number of antecedent variables influencing actual use, either directly or indirectly.
Devaraj et al. (2002)	Measure consumer satisfaction with the electronic commerce (EC) channel through constructs prescribed by 3 established frameworks, namely Technology Acceptance Model (TAM), Transaction Cost Analysis (TCA), and Service Quality (SERVQUAL)	Subjects purchased similar products through conventional as well as EC channels and reported their experiences in a survey after each transaction.	TAM components - perceived ease of use and usefulness - are important in forming consumer attitudes and stultification with the EC channel

Table 1. A sampling of recent TAM-based studies

Based on the Table 1, we can make the following observations about empirically grounded studies that have employed statistical modeling.

1. These studies have been conducted in diverse domains (universities with student respondents, senior executives, medical professionals, merchants, management accountants etc.). The implicit assumption in all these studies is that IS use is

volitional. Hodgson and Aiken (1998) and Rawstorne et al. (2000) document the difficulties and challenges associated with incorporating non-volitional use.

2. These studies are often aimed at comparing or extending theoretical models so as to hypothesize a “new” situation. The “technology acceptance” component of the models is often used as a surrogate for “technology use.” In their study (Plouffe et al., 2000) observe that, “… once merchants have adopted the point-of-purchase equipment needed for the new technology, consumers can use a smart-card as a substitute for cash (p. 211).” Here is a case where a technology adoption decision by merchants has been studied and the usage component of the consumers is assumed away.
3. All such studies measure the perceptions of individuals at a given time by administering a survey instrument. They often do not measure actual use. Either *intention to use* is justified as a surrogate for actual use or other reasons are identified for not measuring actual use. For instance, (Hu et al., 1999) write that, “actual technology use was not used in the research model, a constraint resulting from the early adoption stage of telemedicine technology (p. 97).”
4. While the implications of these studies are useful and add to the common body of empirical knowledge, their applicability to a specific situation can be challenging. For instance Agarwal and Prasad (1999) conclude that “it appears that there may be nothing inherent in individual differences that strongly determines acceptance and, because of the mediating role played by beliefs, it is possible to find alternative means of facilitating technology acceptance and increasing individual productivity (p. 385).” Since such statements lend themselves to a broad range of interpretations, they tend to dilute the value of useful and painstaking research.

Based on these observations, we feel that using “more of the same” approaches to formalize and understand user behavior is fast approaching the stage of diminishing utility for future research. While we agree with the generic TAM approach, the managerial and theoretical utility of such approaches seems to be reaching the saturation point. This is because, in spite of careful sampling and the sophisticated statistical modeling, these approaches fall short of responding to, and accounting for, the real issue at hand. Wexler (2001) captures this problem of the research and reality gap of IS use studies when she observes that, “on the basis of his experience, Davenport concludes that the single most important factor in user acceptance is the relevance of the system to an individual's job success. He was surprised [however] that the Venkatesh (2000) study found that factor to account for less than 30% of perceived ease of use (p. 1).” Such criticism is understandable because none of the studies we sampled (of which we presented a subset) incorporates an individual’s productivity vis-à-vis IS use.

Two studies have identified improvement areas for studying IS use. Szajna (1996) showed that the when using TAM, the model paths change at different time periods while studying 61 graduate students’ email use at different points in time. She measured actual system use and concluded that once individuals have been using an IS, their subsequent intentions are formed from their perception of its usefulness. She highlights the importance of incorporating the temporal dimension in studying IS use by saying that “… the difficulties in the intention-usage relationship from pre- and post-implementation versions make an argument for the consideration of the experience component associated with TAM (Szajna, 1996, p. 86, p. 91)." She further states that, "… the determinants of the role of experience may be the key to understanding the belief-intention-acceptance relationship (p. 92)."

Another study by Bajaj and Nidumolu (1998) addressed feedback from usage to perceived ease of IS use when they studied 27 students using a debugger. They reported strong statistical significance that past (lagged) usage significantly affects current ease of use. They concluded that a longitudinal model is needed to better understand IS usage (Bajaj and Nidumolu, 1998, p. 220). They reflected further that "*merely convincing users of the usefulness of the IS will not influence usage. A perception that the IS is easy to use will lead to a more positive attitude toward using it, which will lead to greater usage* (Bajaj and Nidumolu, 1998, p. 220)." From a system dynamics view, Bajaj and Nidumolu (1998) articulate a reinforcing or a positive feedback loop.

Based on the literature we have reviewed, it appears that is no delineable research contour that could have emerged from the multiple applications of TAM to the study of IS use. The large number of TAM-based studies that is matched by the diversity of users and usage characteristics has resulted in a "fragmented adhocracy (Hirschhiem et al., 1996)" in IS use research. By proposing to extend the TAM by incorporating productivity and including feedbacks, we have applied the correspondence principle[1]. By incorporating the findings of past research in the dynamic hypothesis we have been able to provide an integrative perspective of IS use by addressing the time domain as well.

3. Model development

We have modeled a realistic work situation (shown in Figure 2) where a user of an institutional IS (e.g. email system) is confronted by an institutional change in a new email system. Our primary focus is to model what happens *after* a new information system has been accepted (by an organization) and deployed. In a realistic scenario, volitional aspects of information system use are diluted by the fact that work must go on *regardless of how a user perceives* the system. The model can be identified by five components: IS use, IS-related task, IS-use related stress, computer-related self-efficacy[2] and individual productivity. Appendix B contains the reference modes for validating this study. Figure 2 can also be considered the dynamic hypothesis for this study. The two main loops ("learning" and "IT stress") determine the logic of the simulation model.

IS use

IS use is conceptualized as the time spent using the IS and is measured in hours per day. The use component is premised on the logic that the user calibrates her usage depending on the IS-related task at hand. As the IS-related tasks increase or decrease, the user adjusts her time spent on the IS depending on how much work can be backlogged.

[1] Any new theory, whatever its character--or details--should reduce to the well-established theory to which it corresponds when the new theory is applied to the circumstances for which the less general theory is known to hold (Weidner and Sells, 1968).

[2] Self-efficacy can be defined as one's personal beliefs about his or her ability to perform certain tasks (Bolt et al., 2001)

IS-related task
IS related task is conceptualized as a stream of tasks coming in everyday. Typically, an email user can expect a certain number of incoming mails that need to be responded to. These inputs have been conceptualized in hours per day. As a user responds to emails, her work backlog reduces. The rate at which a user responds to emails is a function of her personal productivity with email use.

IS-use related stress
We assume that every individual has a normative limit on what she considers is a reasonable time spent in reading and replying to emails in a given day. That determines the IS-related stress for that individual depending on the extent to which actual use exceeds that threshold. Stress is dissipated by work completion. An important variable in this subsystem is the tolerable time for IS use. Since some individuals like to use computers and may not mind spending time working on computers, there are others who would like to minimize their interaction with a computer. Tolerable time for IS use allows us to account for that aspect in the model.

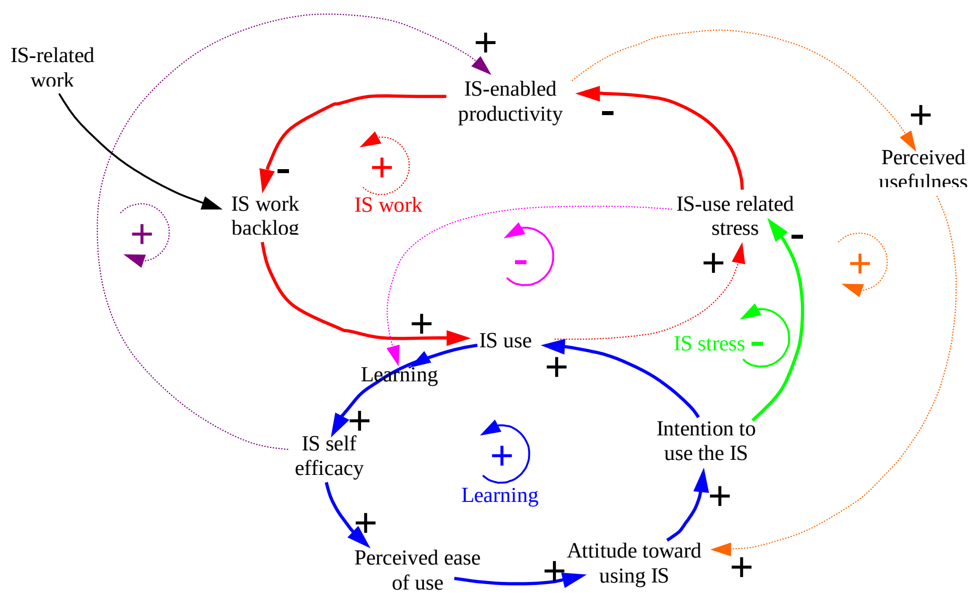


Figure 2. The causal loop diagram showing causal influences.

Learning
Jawahar (2002) reported on the influence of dispositional factors on end-user performance. He identified goal setting and computer self-efficacy as influencing end-user performance. We have incorporated those results to formulate a learning loop that is typically employed in systems dynamics and in psychology. Appendix C formalizes that loop. Thatcher and Perrewe (2002) report a negative relationship between computer anxiety to self-efficacy. We have incorporated that relationship by linking stress due to IS use to learning (which influences IS self-efficacy).

Productivity
The productivity sector accounts for the productivity due to IS use. The level of stress and the level of a user's computer self-efficacy determine productivity. As self-efficacy increases, productivity increases. However, as the stress due to overuse of the IS increases, the productivity is suppressed. In order to aggregate the effects from both stress and efficacy we use an additive term to determine aggregate productivity. This productivity value varies between 0 and 1 and influences the rate at which backlog is reduced.

TAM constructs
Previous research has shown that perceived usefulness and perceived ease of use constitute the two dominant factors that affect an individual's intention to use a system. Different studies (Adams et al., 1992; Hendrickson and Collins, 1996) of the causal relationships between perceived usefulness, perceived ease of use, and system usage have shown that Davis (1989) is correct in proposing that the indirect relationship between perceived ease of use and intention to use, mediated by perceived usefulness, is an important one.

Figure 2 shows that IS-related work is the only exogenous variable. It can be considered analogous to extrinsic motivating factors employed in TAM and TRA. While there are four reinforcing (positive feedback) loops, there are two counteracting (negative feedback) loops. Appendix D shows the flow-rate diagram for the system dynamic model that I constructed using the Stella software.

4. Simulation runs and scenarios

We simulated four scenarios and varied two variables: tolerable work backlog and incoming work. Incoming work has been explained above and the tolerance for backlog is an indicator of the need (intrinsic or normatively determined) to work at a certain level of efficiency. Table 2 summarizes the four static scenarios with an initial self-efficacy level of 20 on a scale of 100.

Run #	Tolerable work backlog	Incoming work
1	Low	Low
2	Low	High
3	High	Low
4	High	High

Table 2. Four simulation scenarios with static assumptions (the low value = 1 and high value 3 for incoming work; the low value = .5 and high value 3.5 for Tolerable backlog)

We have chosen to show results for productivity changes over time. This is because productivity is the outcome variable that informs management of the value of the information system. While there are other variables whose behaviors over time are equally important, we defer referring to those variables until we discuss these results. Figure 3 shows the results of the simulations using static assumptions.

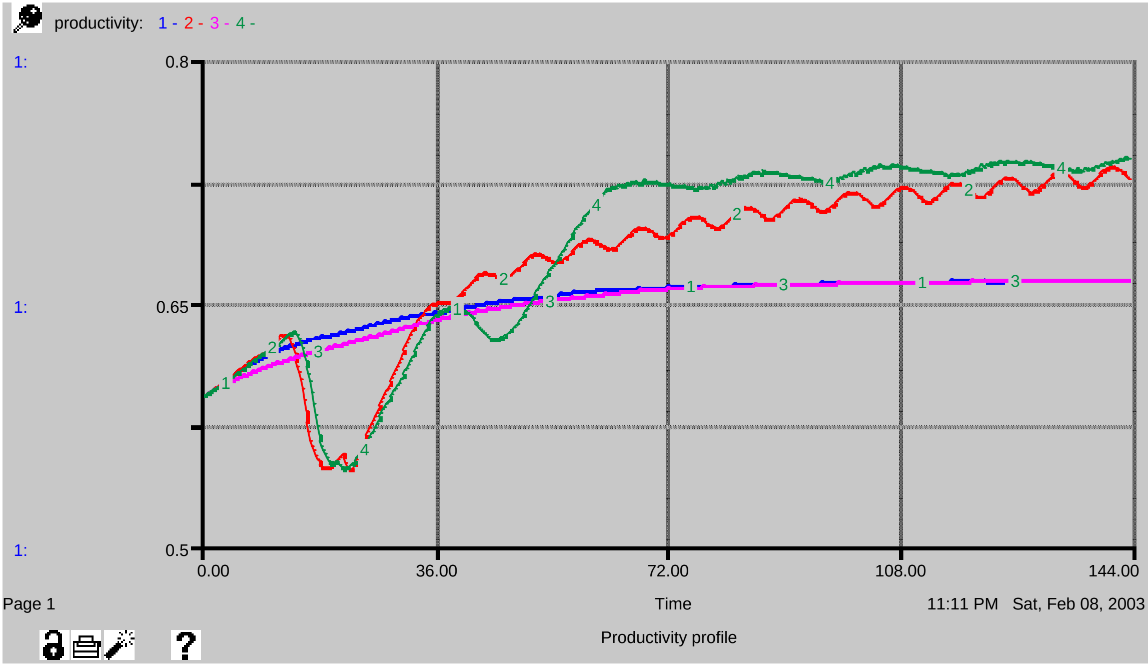


Figure 3. Comparative results for productivity for the simulation runs.

We conducted four more simulation runs described in Table 3 primarily as an aid to distill the implications of the results that I obtained in the main simulation runs. The idea was to communicate to the reader that IS use, as has always been understood, is determined by both intrinsic and extrinsic factors. Incoming work is the exogenous variable and is considered the extrinsic factor.

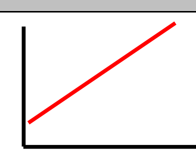
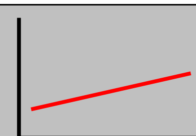
Run #	Tolerable work backlog	Incoming work	Reference mode for intention to use	
1	0.25 hours (low)	1.0 hour per day (low)	Reference mode for intention to use IS is steep (varies from .05 to .30 in 144 days)	
2	0.5 hours (higher)	2.0 hours per day (higher)		
3	0.25 hours (low)	1.0 hour per day (low)	Reference mode for intention to use IS is a slow increase (varies from.05 to . 1 in 144 days)	
4	0.5 hours (higher)	2.0 hours per day (higher)		

Table 3. Four simulation scenarios based on tolerable backlog, incoming work and intention to use.

Results for the next four simulation runs (shown in Table 3) reveal archetypal patterns of behaviors as shown in Figure 4. Archetypal behavior patterns are the equivalent of a theoretical relationship. This is typically what an IS manager would find useful to determine operational and deployment strategies for new software introduction and changes to existing information systems.

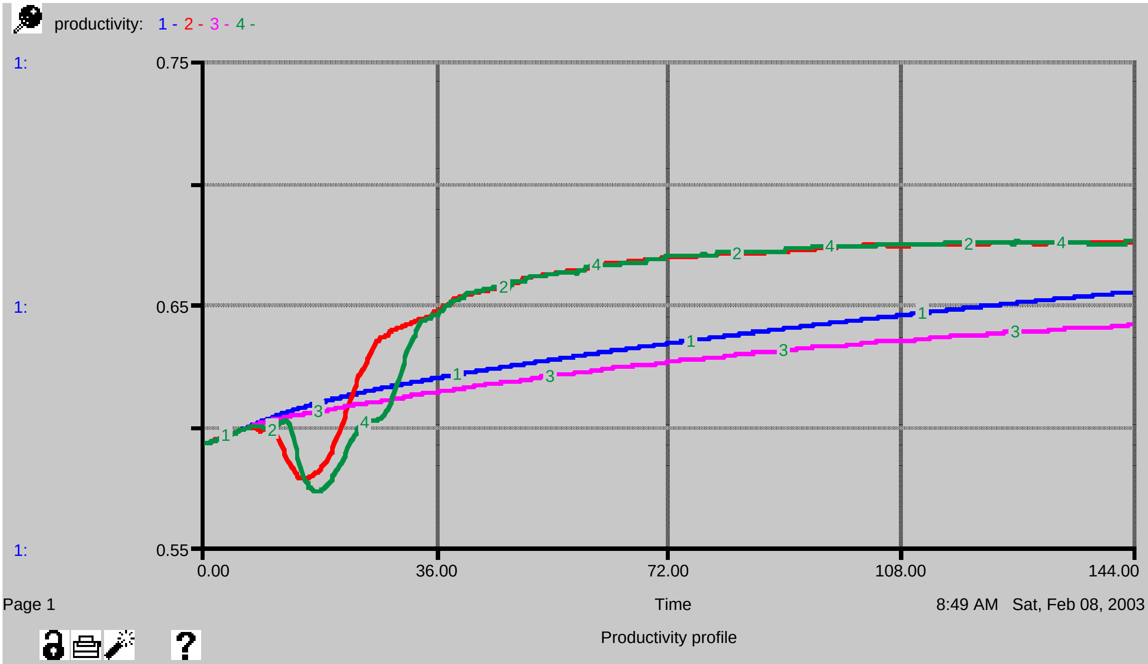


Figure 4. Comparative results for productivity for the simulation runs.

In the next section, we analyze these results and relate them to some of the other variables like initial levels of self-efficacy, efficacy goals and attitude.

5. Analysis

The results in Figure 3 show that the productivity profile for simulation runs 1 and 3 are almost identical. The increase in productivity is most marked in the initial month and then levels off at approximately 0.67. The productivity profile for run 2 is similar to that for run 4 in that there is there is a productivity dip before a sustained increase and subsequent leveling out of the an IS user's productivity. It is important to note that lower productivities are associated with lower work pressures (i.e. lower levels of incoming work). It can be seen that a higher level of IS-related work leads to markedly higher levels of productivity. The productivity levels for runs 2 and 4 tend to converge at around the same level; although the productivity level for run 4 is marginally higher.

These results suggest that in high-performing organizations (where work pressures tend to be higher) IS-productivity will tend to be higher. On the other hand, in organizations and work situations where work loads are light, the level of productivity will taper off at lower levels – in spite of a positive relationship between intention to use the IS and actual IS use (i.e. a minimal level of volitional use that increases as the attitude toward using the IS becomes more favorable). It is useful to note that the time needed to reach the same level of improvement for the low workload case is identical (36 days or about a month). However, what follows is instructive in that the productivity increases to respond to the workload. In the dynamic hypothesis that we have employed, productivity is influenced by IS self-efficacy. The empirical results appear to validate Bolt et al.'s (2001) findings who show that, in the context of training, computer self-efficacy has a greater positive effect on performance when task complexity is high than when task complexity is low. In this case increased IS-related work is equivalent to higher work pressures and leads to higher productivity – especially when we consider the on-the-job learning component.

The other significant finding is that the productivity profile for simulation run 4 is higher that that for simulation run 2. While high IS-related work is common to both these runs, run 4 assumes a higher level of tolerable backlog. This suggests that while positive work pressure is desirable from the productivity standpoint, more meaningful IS effectiveness can be obtained by reducing the pressures associated by IS use by being more tolerant of IS-use related backlogs. While such an approach may result in short-term productivity losses, the long-run productivity increases more that make up for the initial drop in productivity.

Figure 4 shows the effect of changes in intention to use an IS on productivity. Runs 1 and 3 are similar and show gradual increases in productivity. The gradual increase in productivity is understandable because of the low level of IS-related work. The pattern of changes in runs 2 and 4 are those that we have come to expect with higher levels of IS-related work. However, there is a difference between high levels of IS-related work that are associated with different reference mode for intention to use IS. Run 4, describes the productivity profile of a user with a higher level of intrinsic motivation to use an IS. Therefore, it can be seen that some users attain higher IS-enabled productivity faster than others depending on their attitude and, consequently, their superior intention to use the IS. It is, however, instructive to note that in the long run, individual differences are subsumed into the natural limits of productivity and performance.

Therefore, the primary lesson for IS researchers and practitioners is that, given enough time, every IS user will get to the systemically determined productivity levels. However, some users can reach higher levels of productivity in a shorter timeframe – depending on the workload and expected productivity.

6. Conclusions

We have shown in this study that by employing the system dynamics (SD) approach, we can complement existing research and analytical methods for understanding and studying IS use. At the same time, this approach allows both researchers and practitioners to perform meaningful "experiments." These experiments can generate and convey insights that can be generalized and be managerially relevant and applicable.

An important contribution of this study is the recognition and modeling of non-volitional use (exemplified by ERP implementations, institutional software changes and an individual encountering a different IS after joining another organization). The theoretical contribution of this study lies in the identification of the IS use archetype shown in Figure 5. Identification of such archetypes will allow researchers and managers to build and test predictive models. Archetype A behavior is exhibited by individuals who are faced with a higher workload and a higher need for productivity. Archetype B is the productivity profile of users who face a low workload levels and productivity requirement were not stringent. It can be seen that IS-enabled productivity is a function of task requirements.

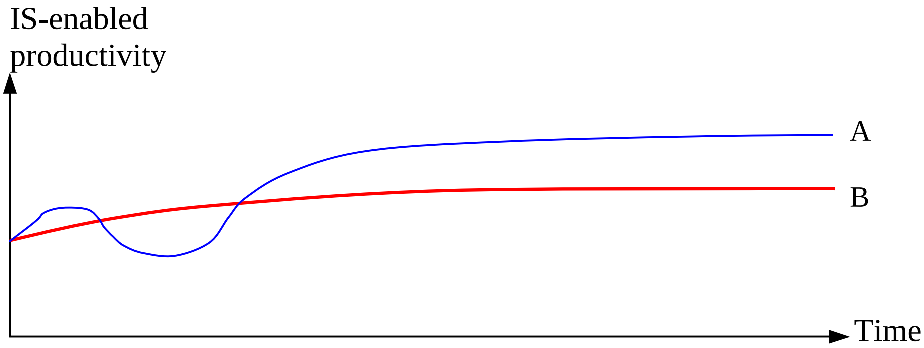


Figure 5. The IS use archetype for an individual

From a theoretical standpoint, archetypes contribute meaningfully to the research discourse on IS use which is dominated by static models that lend themselves to statistical analysis. This opens up increasingly creative research opportunities wherein extended dynamic hypotheses can be tested for diverse environments. If the IS use archetype identified in this study is found to be resilient, it can become a guiding framework to develop customized approaches to introduce and institutionalize new information systems.

It is important to understand from the results of this study that people do not use information systems just because they like to or because they have a positive attitude. In the real world, the mandatory use component overshadows the volitional component; however, the volitional component is crucial in determining the rate at which a specific user can ramp up to higher levels of productivity. This finding has important implications for analyzing and designing policies for IS use. Policy analysis of IS use implies an analysis of the various management decisions that are made during and after the introduction of new or updated information systems. The model described in this study has abstracted out many details of the *individual* IS use process per se, and concentrates on the dynamics of the IS use process, including those factors that affect the performance and intentions of individuals using the IS.

Since this study has been able to demonstrate how IS use can be modeled over time, we have planned future studies that will cover include additional scenarios for IS use (different applications and different implementation schedules) and other variables like the level and nature of user support, initial and ongoing training, and the nature and quality of work processes.

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Appendix A: Behavioral theories used to study IS use

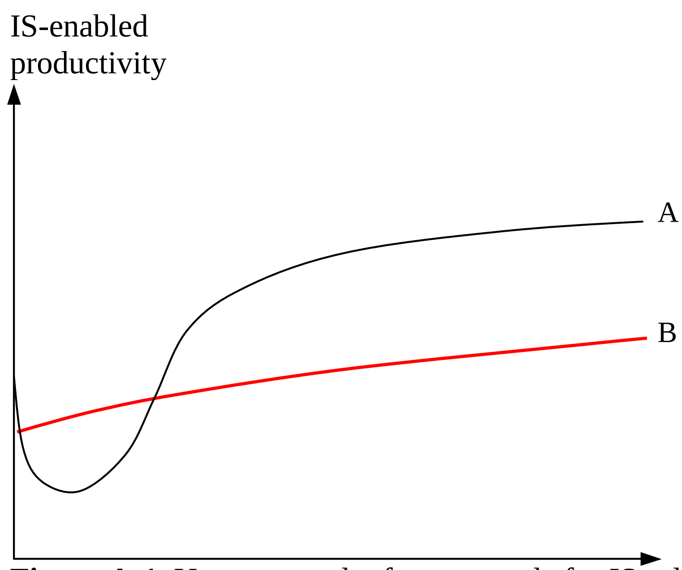
The theory of reasoned action (TRA) defines relationships among beliefs, attitudes, norms, intentions, and behavior. An individual's behavior (e.g., use or rejection of technology) is determined by the person's intention to perform the behavior, and this intention is influenced jointly by the individual's attitude and subjective norm, defined as the person's perception that most people who are important to him think he should or should not perform the behavior in question. According to the theory of reasoned action, attitudes toward a behavior are determined by beliefs about the consequences of that behavior.

The technology acceptance model (TAM) is a management information system-specific model derived from theory of reasoned action (TRA). The technology acceptance model predicts that user acceptance of any technology is determined by two factors: Perceived usefulness (U) and Perceived ease of use (EOU). Perceived usefulness is defined as the degree to which a person believes that use of the modeling approach will enhance his or her performance. Perceived ease of use is defined as the degree to which a person believes that the modeling approach will be free of effort. Since TAM is based on Ajzen and Fishbein's (1980) Theory of Reasoned Action, which recognizes the importance of social norms in influencing individual behavior, the more a modeler perceives that others (in the project or organization) who are important to him think he should perform a behavior (use any or a specific modeling framework), the more s/he will intend to do so (Ajzen & Fishbein, 1980, p. 57).

Theory of planned behavior holds that attitudes, subjective norms, and perceived behavioral control are direct determinants of intentions, which in turn influence behavior. Taylor and Todd (1996) state that the influence of peers and the influence of superiors are antecedents to the subjective norm. Taylor and Todd also view self-efficacy, resource-facilitating conditions, and technology-facilitating conditions as determinants of perceived behavioral control. Tools supporting different modeling frameworks do not exist in a vacuum and neither do software practitioners. The attitudes of clients and peers can positively or negatively influence the attitudes and behavior of individuals. Software development organizations are cultures with many different factors contributing toward their growth and development, and unfortunately at times, their dogmatic beliefs about modeling approaches and tools. Perceived behavioral control refers to "people's perception of the ease or difficulty of performing the behavior of interest" (Ajzen, 1991). If behavior is not under complete volitional control, the performers need to have the requisite resources and opportunities in order to perform the behavior. The perception of whether they have the resources will affect their intention to perform the behavior, as well as the successful performance of the behavior. There is significant evidence in the literature that process-oriented modeling approaches are considered easier to use. It is quite possible that based on past experience or because of role requirements, individuals tend to perceive more or less control respectively over use of modeling approach.

Appendix B: Reference modes

In order to obtain reference modes, I interviewed a diverse group of email users. These included students as well as faculty members in a university as well as a group of email users in a corporate setting. A change in the email system was common to both sets of users. Common to both populations was a change in the email system – from 'pine' to 'Webmail' for the university and from pine to Lotus Notes for the corporate site. For both sites we found that end-user reported user productivity increased over time after the new email system was implemented (shown in Figure A-1). However, some use users did not report significant increases in their IS-related productivity. Others reported significant improvements. Almost all users reported high satisfaction with the email system with some complaining about occasional problems with email outage.



A – This was a typical productivity profile reported by users who faced a high workload and stringent productivity requirement (low backlogs).
B – This was a typical productivity profile reported by users who faced a low to moderate workload levels and productivity requirement were not stringent (high backlogs were tolerable).

Figure A-1. User reported reference mode for IS-related productivity

The other relevant information for modeling purposes was that users who did not report very high productivity scores did not use the email intensively. Those reporting high productivity scores tended to be "power users" or those who received and sent a high volume of email. Users reported that they typically spent about one to two hours on the email and generally checked emails. Heavy users spent anywhere between 2-3 hours per day using the email system. Most of the users time in the initial stages of the new email deployment was spent in learning new functionalities and shortcuts and developing expertise in using those features. Another time-consuming activity included (re)-building and managing address-books.

Appendix C: Assumption of the learning curve

Psychologists interested in learning theory study learning curves. A learning curve is the graph of a function L(t) , the performance of someone learning a skill as a function of the training time t. The derivative dL/dt represents the rate at which self-efficacy improves. If L_{Max} is the maximum level of performance of which the learner is capable, it is reasonable to assume that dL/dt is proportional to L_{Max}-L(t). (At first, learning is rapid. Then, as performance increases and approaches its maximal value, the rate of learning decreases.) Thus

$$\frac{dL}{dt} = k(L_{Max} - L(t))$$

where k is a positive constant. We can solve this linear differential equation to sketch the learning curve.

$$\frac{dL}{dt} + kL = kL_{Max}$$

Let

$$I(t) = e^{\int k dt} = e^{kt}$$

If we multiple the differential equation by I(t), we get

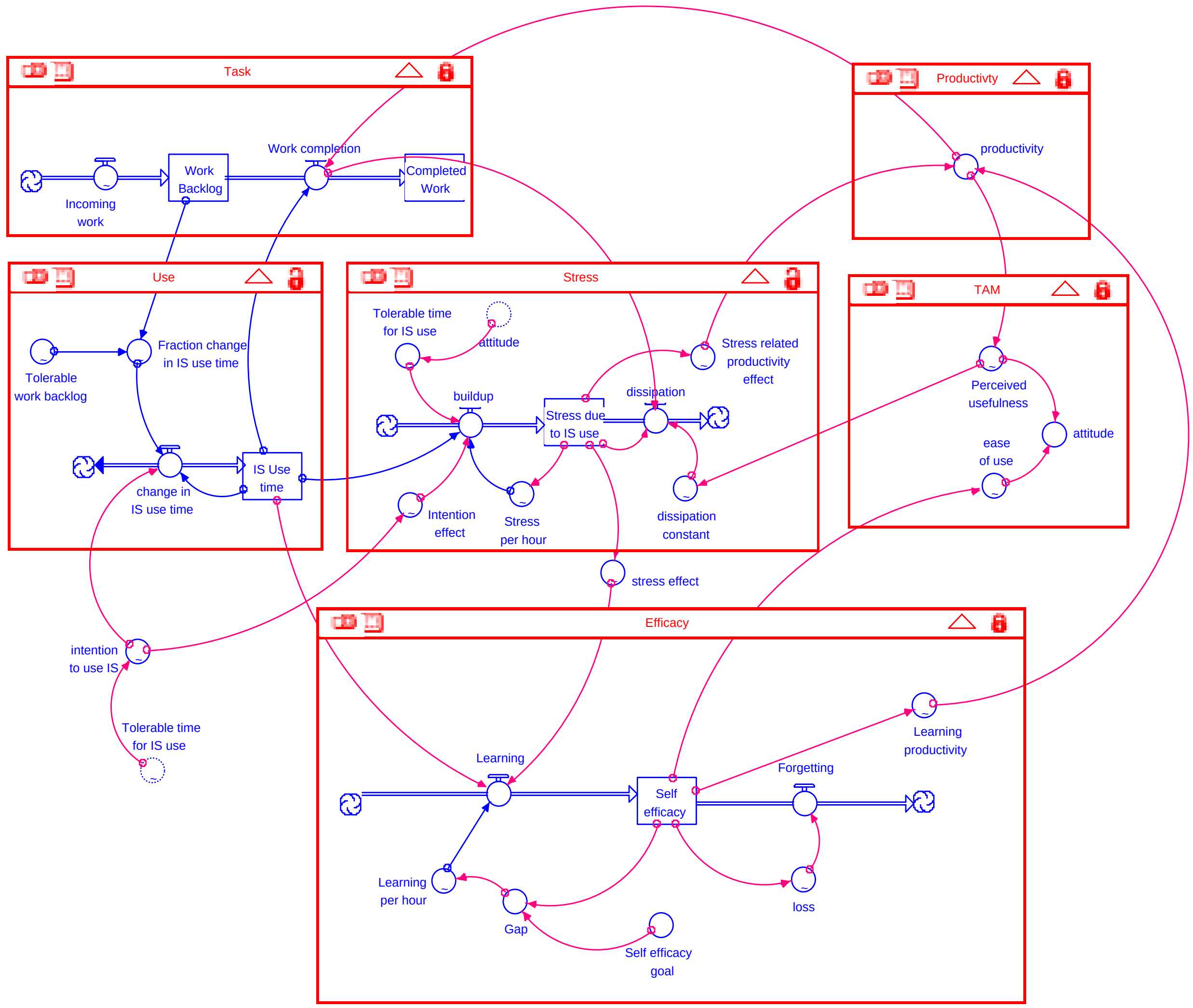
$$e^{kt}\frac{dL}{dt} + kLe^{kt} = kL_{Max}e^{kt}$$

$$(e^{kt}L)' = kL_{Max}e^{kt}$$

$$L(t) = e^{-kt}(\int kL_{Max}e^{kt}dt + C) = L_{Max} - Ce^{-kt}$$

where the constant C has to be positive since it's reasonable to assume $L(0) < L_{Max}$.

Appendix D. The system dynamics model



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