A system dynamics model of post-installation use of enterprise information systems

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Abstract: *An enterprise information system, e.g. a system for Enterprise Resource Planning or Customer Relationship Management, is important for any organization to carry out its business activities. Even when the upstream activities of selection or development of such a system, its installation and appropriate user training are carried out effectively, the subsequent use of the system does not always result in meeting the expectations to carry out the work of the enterprise. Published literature is rich in covering the initial acceptance and adoption of such information systems, but is rather sparse in covering the dynamics of post-installation use of the systems. This is particularly so for the critical time period immediately after the system is installed when enterprises have the opportunity to take corrective actions, if needed. Our system dynamics model is an initial attempt to capture the complex dynamic interactions among the characteristics of the organization, business processes, users, the enterprise information system, and interventions by the organization. Our results show that the model can be used to understand the impact of organizational characteristics and interventions on profiles of system use and work done via the system after an enterprise information system is successfully installed.*

Keywords: enterprise information systems, continuing usage, post-installation use

Introduction

Almost all enterprises use information systems (IS) that are required to carry out the enterprises' business processes. Enterprise Resource Planning (ERP) systems, Customer Relationship Management (CRM) systems, Budget and Accounting systems are examples of such enterprise-wide information systems. Enterprises invest a significant amount of resources to develop/acquire such systems. Employees and managers of the enterprise are required to use the system to carry out the appropriate business processes. After such a system is effectively developed/acquired and installed, the system often fails to reach an expected steady state level of use required to carry out the work of the enterprise. Even when the steady state use of the system is as required, the transition period often shows a "productivity dip" (Jenkins, 2001; Okrent and Vokurka, 2004; Volkoff et al., 2004). Therefore, it has been of academic and practical interest to investigate the dynamics of why the outcomes, in terms of system use and work done via the system, have been uneven.

The academic discourse on understanding the causes of such uneven outcomes has focused primarily on the initial selection/acceptance of the systems and on the subsequent steady-state levels of use reached for such systems. The focus of the model presented in this paper is on the transition period immediately after the system is installed. For major information systems, the transition period, e.g. first 6-12 months, is critical because any problems with the system during that time period can have significant impact on users, and potentially on the subsequent steady-state use. That is also the time period when management of the enterprise can make corrective interventions, such as for system maintenance, additional training and support. It is important to know which combinations of interventions are likely to improve the chances of effective use of the system, and also to reduce the extent and duration of any "productivity dip" during the transition period.

Most of the studies so far have employed variance theoretic or static models, or looked at multiple snap-shots over time. Such approaches do not fully address the dynamic interplay between the characteristics of the system, business processes and the users, and the feedbacks from the use of the system on those characteristics to get work done. The system dynamics model presented in this paper is an initial attempt to capture the interplay between those characteristics, the feedbacks and management interventions to get insight into post-installation use of such required enterprise information systems.

Background

The Information Systems domain has a rich portfolio of research papers on acceptance of information technology and systems. For instance, Venkatesh et al (2003) integrated a rich tradition of research and presented a unified model for user acceptance of information technology as a tool to assess the likelihood of success of new technology introductions. Bagchi et al (2003) adopted a path analytic approach to examine acceptance of enterprise resource planning systems at the individual level. Gattiker and Goodhue (2002 and 2005) extended the thinking by investigating the result of ERP software on changing business processes, particularly at a subunit level of organizations. Given the varying experiences of organizations in the use of enterprise information systems, Schwarz and Chin (2007) encouraged broadening our understanding of IT acceptance to behavioral usage, and Venkatesh et al (2007) called for further research on interventions, contingencies and alternative theoretical perspectives.

While the studies mentioned above were focused on acceptance of IT/IS, there were other studies that looked beyond just acceptance and on the use of those systems over time. Orlokowski (1993) studied use of CASE tools and concluded that adoption and use of CASE tools depends on IS context, organizational context and environmental context.

Bhattachejee (2001) presented an expectation-confirmation model for post-acceptance use of information systems. Bhattacherjee and Premkumar (2004) went further to propose a temporal model for user beliefs and attitudes because those are key perceptions driving IS usage and also because those perceptions may change over time. Mendoza (2008) presented the results of a longitudinal study on continued use of a Learning Management System that the influences supporting users' decision to adopt an IS may not be sufficient to encourage continued use of that IS. Jasperson et al (2005) also looked at post-adoptive behaviors associated with IS, specifically the extent of use of functionalities built into the system. These studies extended the research from IS acceptance to IS continued use.

While the studies mentioned above have looked at the longitudinal use of IS, they have approached it by taking multiple snapshots using static models, with minimal feedbacks that are commonly inherent in continued use of enterprise information systems. Clark and Jones (2008) used system dynamics approach for assessment of structure and behavior of management support systems. Jones et al (2008) also used system dynamics approach to look at post-installation perception and behavior for ERP systems in practice after it has reached steady-state, at least three years after the initial installation of the system. There appears to be a gap in studying the dynamics of use of enterprise information systems immediately after installation, and also in addressing the effect of management interventions on the continued use of the systems. It is important to fill that gap because that is a critical time period when organizations can intervene to take corrective actions, as needed, if the use of the system is not producing expected results. The system dynamics model presented in this paper is an initial attempt to fill that important gap.

Concepts for the system dynamics Model

We chose to use system dynamics approach for our study because it allows for modeling simple causal linkages that can be integrated to study complex temporal interactions between multiple components and multiple feedbacks. We were encouraged by previous uses of this approach by Clark and Jones (2008), Jones et al (2008) and others on similar topics, such as software development, knowledge management, software quality assurance and software project management (Abdel-Hamid (1988), Abdel-Hamid and Madnik (1989), Abdel-Hamid et al (1999), Akkermans and van Helden (2002) and Gurud and Kumarswamy (2005)).

The "system" to be modeled consists of three **components**. A set of ***business processes (BP)*** that has been identified for inclusion in an information system will be a component of the "system". The ***information system (IS)*** that provides the features and functions required for that set of business processes (BP) will be the second component of the "system". The IS may support either all or a subset of those business processes. The IS may be custom-developed or acquired as a software package from a vendor with or without customization. The information technology platform (e.g. hardware, network, operating systems, etc.) on which the IS will operate will not be a component of the "system" and is assumed to perform as required. The ***users*** of the IS will be the third component of the “system”. These users may consist of employees and managers of the enterprise, and external individuals who need to use the IS to carry out the business processes. These users will need to know the business processes (BP) and how to use the Information System (IS).

The **exogenous variables** to the model will consist of initial conditions of the components of the system and subsequent management interventions. The ***initial conditions*** will be determined by an upstream project covering the identification of the set of business processes for inclusion in the IS, the development or acquisition of the IS, user training and IS installation. As the IS is used to carry out the business processes, management of the enterprise often intervenes in an effort to gain the most from the IS. These ***interventions*** could be operational (for IS maintenance, users’ IS skills training and users’ BP skills training) and strategic (for BP enhancements and IS enhancements).

The **endogenous variables** of interest from the model are the extent to which the ***IS is used*** and the ***work done via the IS***. These variables will depend on the exogenous variables (initial conditions from the project and any interventions) and also on the extent of concordance between the business processes, the IS capability and the users’ skills as shown in Figure 1.

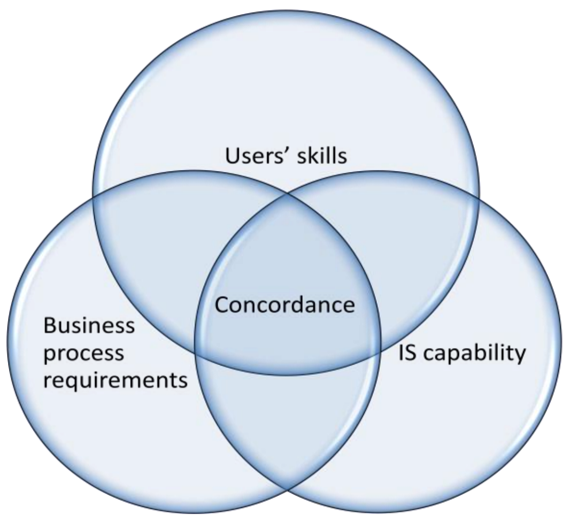


Figure 1. Concordance between BP, IS and Users’ skills

This concordance is incorporated in the model by three other endogenous variables – IS capability, and users’ skills in IS and in BP. The IS may or may not completely cover all the business process requirements. If the IS is custom-developed, then the IS is expected to incorporate all the required BP. If the IS is acquired as a software package, it is quite likely that the so-called “best practices” implemented in the software may not match the required BP of the enterprise exactly. The closer ***IS capability*** is to the required BP, the higher will be the use of IS and the work done via IS. Any deficiency in IS capability with respect to the required BP can be reduced or eliminated over time by strategic interventions to enhance either the IS to fit the BP or the BP to fit the IS.

Users will need skills to use the IS and also skills in the business processes themselves to get work done via the IS. Thus, ***users' IS skills and BP skills*** are two other endogenous variables of the model. If those skills are less than required, in terms of the breadth and depth the processes and the features/functions of the IS, the use of IS and work done via IS will be correspondingly less. The training provided in the upstream project can enable users to acquire the necessary skills in IS and in BP. However, users rarely acquire and retain all those skills after such one-time training. As the users use the IS, they can acquire the missing skills. On the other hand, if the users do not use their skills, they may loose them. Operational intervention in the form of on-going training and support, for both IS skills and BP skills, can increase the skills to the required level.

There will be one other endogenous variable of the model that will affect the IS use and work done via IS, namely ***IS quality***. The upstream project to develop or acquire the IS will have carried out testing and quality assurance to eliminate any errors known at that time. So, the known quality of the IS at the beginning can be high but errors/bugs are always discovered as the IS is used. Lower quality of the IS will reduce the use of IS and the work done via the IS. Operational intervention in the form of IS maintenance can reduce or eliminate the errors/bugs in the IS to restore its known quality.

The initial values of the endogenous variables (IS capability, IS quality known, users' IS skills and users' BP skills) will be determined by the effectiveness of the upstream project that selected/developed the IS, trained the users and installed the IS. Conceptually, the relationships between the endogenous variables of interest and other endogenous variables will be as follows.

IS use = f (IS capability, IS quality, users' IS skills)

Work done via IS = f (IS use, users' BP skills)

Over time, there will be two significant **feedbacks** from the extent of IS use that will affect the endogenous variables of IS quality known, and users' IS skills and BP skills. The influence of these feedbacks will depend on **factors** that will vary from one enterprise to another. It is commonly understood and accepted that the more IS is used, the more users will learn from it to increase their IS and BP skills. The converse is also commonly understood and expressed by the old addage "use it or lose it" (Boudreau, 2003). Conceptually, this implies the existence of an acceptable ***threshold of IS use***. If the actual IS use is above that threshold, users' will increase their skills, and lose their skills if actual IS use is below that threshold. We posit that such a threshold will depend upon the commitment of the users to the system. Higher the commitment of the users to the IS, there will be less resistance to use it, and therefore the acceptable threshold of IS use will be lower. Malhotra (2005) defined dimensions of such commitment as (1) affective conceptualization commitment that based on internalization and identification by individuals, and (2) cognitive conceptualization commitment that is based on compliance. Even if the commitment along the second dimension is given because use of enterprise information systems is required, commitment along the first dimension cannot be assumed to exist fully and may vary from enterprise to enterprise. We also posit that management would be able to increase the affective commitment of users by appropriate incentives and disincentives, i.e. going beyond simply mandating the use of IS. So, conceptually the feedback from IS use on users' skills will be:

If IS use > (IS use threshold) THEN users' skills will increase ELSE users' skills will decrease

The extent of such increase or decrease in users' skills depending on IS use would depend on the individuals, and can be defined by two other factors, namely IS skills factor and BP skills factor. Such changes will normally attenuate over time. So conceptually the change in users' skills due to the feedback from IS use will be:

Change in users' BP skills = f (BP skills factor, existing BP skills, IS use, time)
Change in users' IS skills = f (IS skills factor, existing IS skills, IS use, time)

Even though the IS is usually tested before installation, i.e. all known bugs/errors are removed, the system is completely error free and new errors are always discovered as the system is used. The rate at which errors are discovered, IS quality factor**,** would depend upon how well the IS was tested - 0 if the IS was well tested (ideal) and 1 if testing was done very poorly. The rate of finding such errors normally decreases over time. So, conceptually the feedback from IS use on IS quality known will be:

Change IS quality known = f (IS quality factor, IS use, time)

The endogenous variables (IS capability, IS quality known, users' IS skills and users' BP skills) will also be effected by management interventions in terms of resources allocated by the management to help improve the use of IS and the work done via the IS. The impact each of these interventions will have on the corresponding endogenous variables can be defined as coefficients (a through g) which will depend on the enterprise, the IS and the effectiveness of the intervention.

Change in IS capability = f (a, $ for BP enhancements)
Change in users' BP skills = f (b, $ for BP enhancements)
Change in IS capability = f (c, $ for IS enhancements)
Change in users' IS skills = f (d, $ for IS enhancements)
Change in IS quality known = f (e, $ for IS maintenance)
Change in users' IS skills = f (f, $ for IS training)
Change in users' BP skills = f (g, $ for BP training)

Constructs of the system dynamics model

Since the objective of the model is to investigate IS use and work done via IS relative to the highest that can be achieved, the model has been constructed with ***four stocks*** as gaps for each of the four endogenous variables.

IS capability gap is defined as the gap between business process requirements and the capability of the IS to carry out those processes exactly - on a scale of 0 to 1. If the all required business processes are exactly available in the IS, the gap will be 0. If none of the processes are available in the IS, the gap will be 1. The gap can be reduced either by enhancing the IS, or by enhancing the business processes to fit the IS.

Users IS skills gap is the gap in users' skills to use all the capabilities of the IS, on a scale of 0 to 1. 0 will mean users have the skills to use all the IS capability, 1 will imply users do not know how to use the system at all. Users reduce the gap by improving their skills if they use the system beyond the IS use threshold, and conversely users will increase the gap or loose their skills if the system use is less than the IS use threshold. This gap will increase if IS is enhanced, and can be reduced by allocating resources for IS skills training.

Users BP skills gap is the gap in users' skills to carry out all the required business processes, on a scale of 0 to 1. 0 will mean users have the skills to carry out all the BPs, 1 will mean users do not know how to carry out any of the BPs. Users reduce the gap by improving their skills if they carry out the processes by using the system beyond the IS use threshold, and conversely users will increase the gap or loose their skills if the system use is less than the IS use threshold. This gap will increase if BP is enhanced, and can be reduced by allocating resources for BP skills training.

IS quality known is the known quality of the IS, on a scale of 0 to 1. 0 will mean totally useless IS, and 1 will mean that there are no known bugs. It is well known that IS cannot be tested to remove all the bugs, so even if the known quality is 1 at the beginning, bugs will be discovered as the system is used, thus reducing the IS quality known - more initially and tapering down over time.

In the model, the two endogenous variables of interest are calculated based on the levels of the four stocks as follows.

IS use = (1 – IS capability gap) * IS quality known * (1 - Users' IS skills gap)

Work done via IS = IS Use * (1 - Users' BP skills gap)

The formula for work done via IS needs some explanation. If the users’ BP skills gap matches their IS skills gap, meaning the users do not know about specific business processes and also do not know how to use the IS for those same specific processes, then the work done via IS will not get reduced relative to the extent of IS use. However, if users’ BP skills gap is for specific processes entirely different from the processes relevant to the IS skills gap, then the work done via IS will be less, proportional to the BP skills gap as represented in the above equation. Since our current model does not distinguish between individual business processes, the above formula essentially denotes a lower bound of work done via IS, and the upper bound will be equal to IS use.

The initial value of each of the four stocks is entered as exogenous variables in the model depending upon the outcome of the upstream project. For example, if the upstream project was carried out perfectly, an ideal scenario, then the initial value of each of the four gaps will be set to 0. Five external interventions are included in the model as exogenous variables - $ for BP enhancement, $ for IS enhancement, $ for IS maintenance, $ for IS training and $ for BP training. The factors and coefficients are coded into the equations in the model.

Since the purpose of the model is to investigate the transition period of 6-12 months, the ***unit of time*** for the model is assumed to be a week.

The schematic of the stock and flow diagram of the constructed model, as implemented in STELLA software, is given in Figure 2 and the equations included in the model are given in Attachment 1.

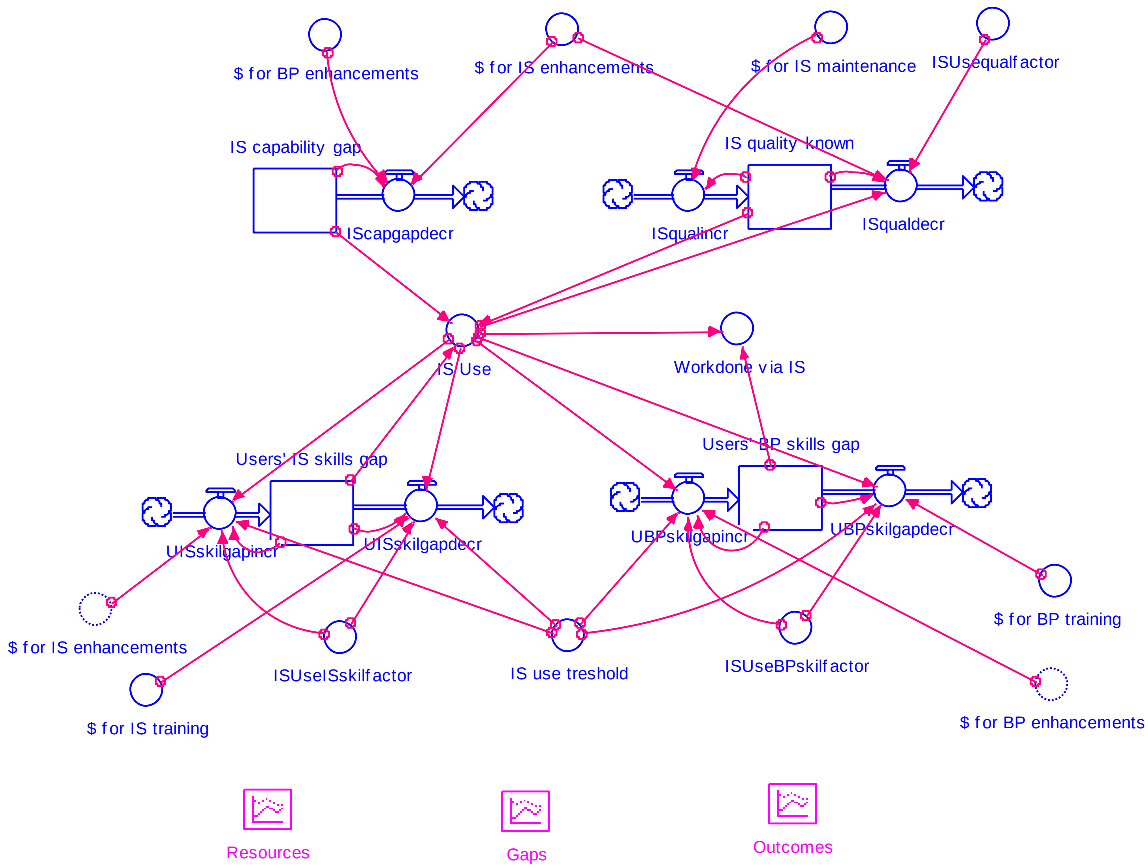


Figure 2. Stock and flow diagram

Results from the model for selected scenarios

Since we were interested in studying the dynamic interactions between the exogenous variables determined by the upstream project to install the IS and subsequent management interventions with the organizational characteristics, we ran the model for three scenarios with different effectiveness of the upstream project in installing the IS. Those scenarios determined the initial values of the three stocks in the model, as follows. The IS was assumed to have no known errors/bugs at the beginning of the model runs.

Scenario 1: Realistic outcomes for automating existing business processes, and IS skills training resulting in only 50% retention by users. Training in BP skills is not required because the processes are not changed. Thus the initial values of the four stocks were set as follows:

IS capability gap = 0 (all required processes implemented in the IS)
IS quality known = 1 (no known bugs in the IS)
Users' BP skills gap = 0 (Users already know existing business processes)
Users' IS skills gap = .5 (Users retained only 50% of skills from IS training)

Scenario 2: Realistic outcomes for reengineered business processes, and training in IS skills and BP skills resulting in only 50% retention by the users. Thus the initial values of the four stocks were set as follows:

IS capability gap = 0 (all required processes implemented in the IS)
IS quality known = 1 (no known bugs in the IS)
Users' BP skills gap = .5 (Users retained only 50% of skills from BP training)
Users' IS skills gap = .5 (Users retained only 50% of skills from IS training)

Scenario 3: Realistic outcomes for IS supporting only 80% of the reengineered business processes, and training in IS skills and BP skills resulting in only 50% retention by the users. Thus the initial values of the four stocks were set as follows:

IS capability gap = .2 (80% of all required processes implemented in the IS)
IS quality known = 1 (no known bugs in the IS)
Users' BP skills gap = .5 (Users retained only 50% of skills from BP training)
Users' IS skills gap = .5 (Users retained only 50% of skills from IS training)

It was assumed that only limited resources are available for operational interventions ($3 for every unit of time) and for strategic interventions ($3 for one time allocation). The following eight variations in allocating the on-going $3 for operational interventions were considered.

- No resources for IS maintenance, IS skills training and BP skills training,
- All $3 for only one of the three interventions,
- Split evenly between two of the three interventions, and
- $1 each for the three interventions

Similarly, the following three variations in allocating one time $3 for strategic interventions were considered.

- All $3 for only one of the two interventions (IS enhancements or BP enhancements)
- $1.5 each for IS enhancements and BP enhancements

Staff members of the organization were assumed to be not very committed to use the new information system and therefore less tolerant of problems in using the system. Hence, IS threshold was initially set high at 0.8. The model was also run for medium (0.5) and low (0.2) values of the IS use threshold assuming that management is able to influence staff to be more committed to use of the system.

Since we were interested in getting only the profiles of dynamic interaction between the exogenous variables on the endogenous variables of IS use and work done via the IS, we used the following plausible values of the factors and the coefficients as appropriate for a fictitious organization.

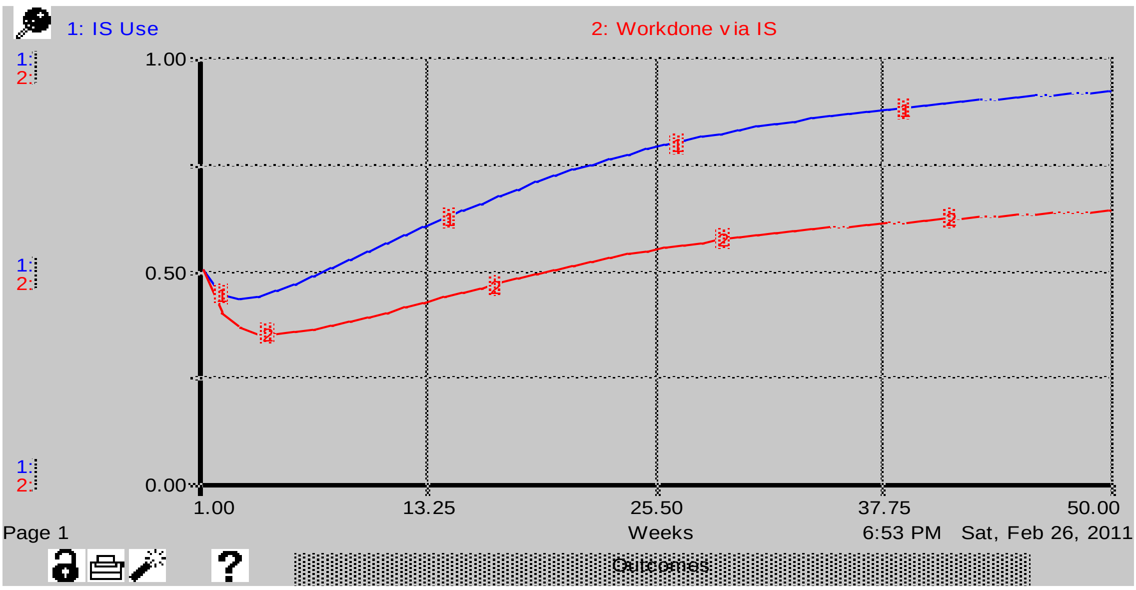
- IS Use to IS skills factor = 0.5,
- IS Use to BP skills factor = 0.5,
- IS Use to IS quality factor = 0.2,
- $ for IS maintenance on IS quality known = 0.05,
- $ for IS training on Users IS skills gap = 0.05
- $ for BP training on Users BP skills gap = 0.05
- $ for BP enhancements on IS capability gap = 0.1
- $ for BP enhancements on Users BP skills gap = 0.1
- $ for IS enhancements on Users IS capability gap = 0.1
- $ for IS enhancement on IS quality known = 0.2

Unit of time being one week, the model was run for 50 weeks. A summary of results from the full set of model runs for all scenarios and all variations of interventions are given in tabular form in Attachment 2.

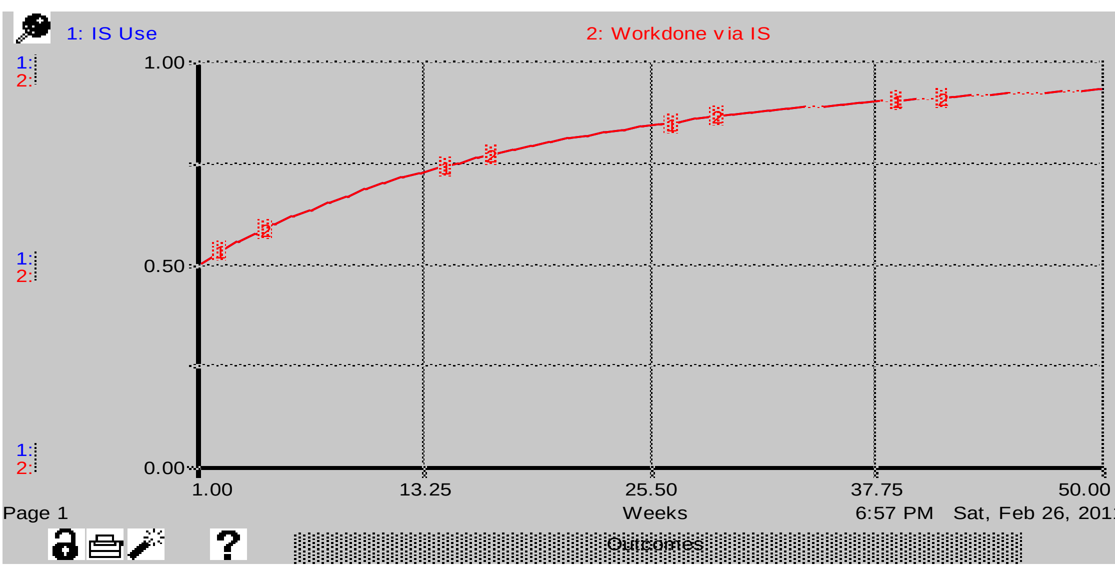
Scenario 1 results:

Table 1 in Attachment 2 shows that if there is no operational intervention, IS use will steadily go down from the initial value of 0.5 ending at 0.16, and the work done via IS from 0.5 to 0.07. Both IS use and the work done decrease steadily because as the IS is used, errors/bugs get discovered that reduces both IS use and work done. As IS use goes lower than the IS use threshold, users' IS and BP skills also erode, further reducing IS use and work done. Three of the seven variations in operational interventions also show steadily decreasing IS use and work done, while the remaining four show an initial dip followed by asymptotical increase. It is interesting to note that operational intervention of $1.5 for IS maintenance and IS training each will produce the highest IS use in the steady state by the end of the year but less work done via the IS. Allocating $1 each for IS maintenance, IS skills training and BP skills training seems to give the most work done through IS in the steady state. In both these allocations, there is an initial dip in IS use and work done via IS during the transition period.

Table 1 in Attachment 2 also shows the results of running the model for operational intervention of $1.5 for IS maintenance and IS training each, and IS use threshold of 0.5 and 0.2. For these lower values of the IS use threshold, the initial dip in IS use disappears and the IS use increases more rapidly to a somewhat higher use in the steady state by the end of the year. Figure 3 graphically shows the changes in IS use and work done for this scenario for the above mentioned operational intervention and the high (0.8) and low (0.2) values of IS use threshold.



IS use Threshold = 0.8



IS use Threshold = 0.2

Figure 3. Scenario 1: Resource allocation of $1.5 for ISM and ISS; none for BPS

Scenario 2 results:

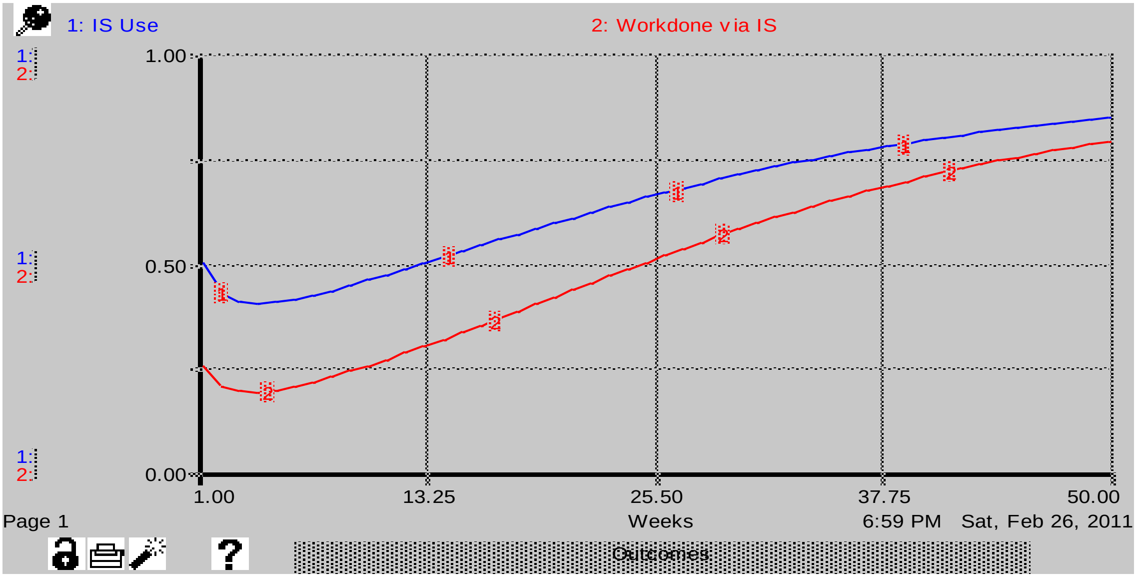
Table 2 in Attachment 2 shows that if there is no operational intervention, IS use will steadily go down from the initial value of 0.5 ending at 0.16, and the work done from 0.25 to 0.03. Both IS use and the work done decrease steadily because, as in scenario 1, as IS is used, errors/bugs get discovered that reduces both IS use and work done. As IS use goes lower than the threshold, users' IS and BP skills also erode, further reducing IS use and work done. As in scenario 1, three of the seven variations in operational interventions also show steadily decreasing IS use and work done, while the remaining four show an initial dip followed by asymptotical increase. Allocating $1.5 for IS maintenance and IS training each will produce the highest IS use in the steady state by the end of the year but the work done via IS is significantly low. However, allocating $1 each for IS maintenance, IS skills training and BP skills training seems to give the most work done through IS in the steady state.

Table 2 in Attachment 2 also shows the results of running the model for operational intervention of $1 each for IS maintenance, IS training each and BP skills training, and IS use threshold of 0.5 and 0.2. For these lower values of the threshold, the initial dip in IS use disappears and the IS use increases more rapidly to a somewhat higher use by the end of the year. Figure 4 graphically shows the changes in IS use and work done in this scenario for the above mentioned operational intervention and the high (0.8) and low (0.2) values of IS use threshold.

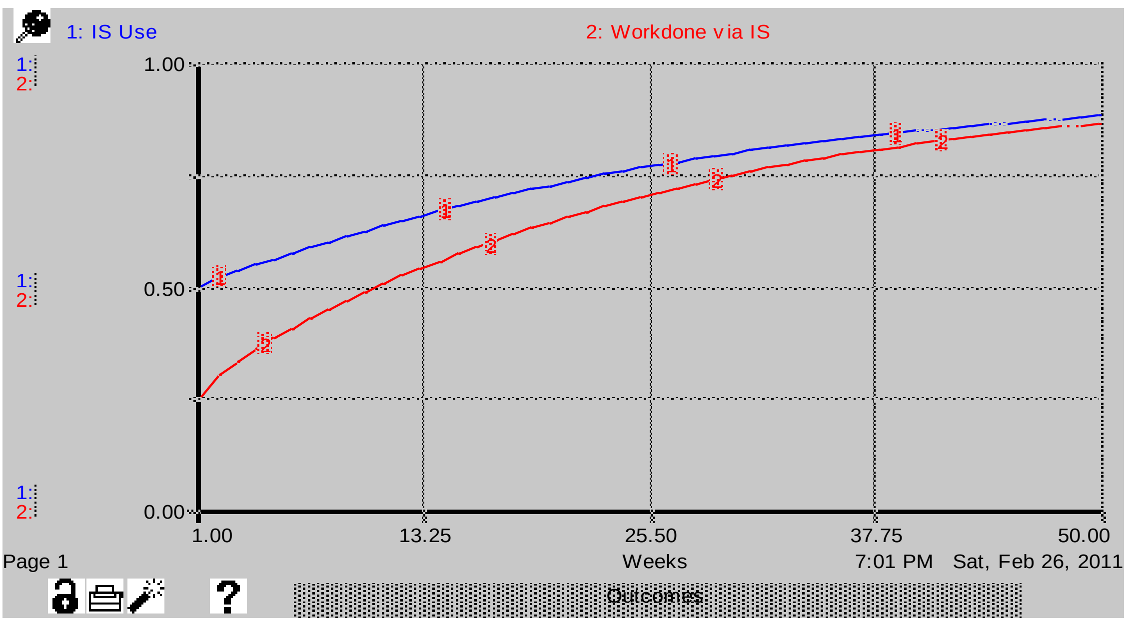
Scenario 3 results:

Unlike scenarios 1 and 2, this scenario can certainly use operational as well as strategic interventions because of the gap between IS capability and BP requirements. The initial condition in this scenario is similar to that for scenario 2 except for the IS capability gap. Therefore, it was not surprising that operational intervention of $1 each for ISM, ISS and BPS provided for the most work done through IS in the steady state. That operational intervention allocation was used to run the model for different allocation of strategic interventions.

Table 3 in Attachment 2 shows the steady state IS use and the work done via IS for the three alternative allocation of strategic intervention, namely all $3 for BP enhancements or IS enhancements, or equally distributing it among those two interventions. Essentially, the different allocation of strategic intervention provides almost the same result, even for varying the time when the strategic intervention occurs. Figure 5 graphically shows the changes in IS use and work done for this scenario for operational intervention equally distributed among ISM, ISS and BPS, and strategic interventions also equally distributed among BP and IS enhancements.



IS use Threshold = 0.8



IS use Threshold = 0.2

Figure 4. Scenario 2: Resource allocation of $1 each for ISM, ISS and BPS

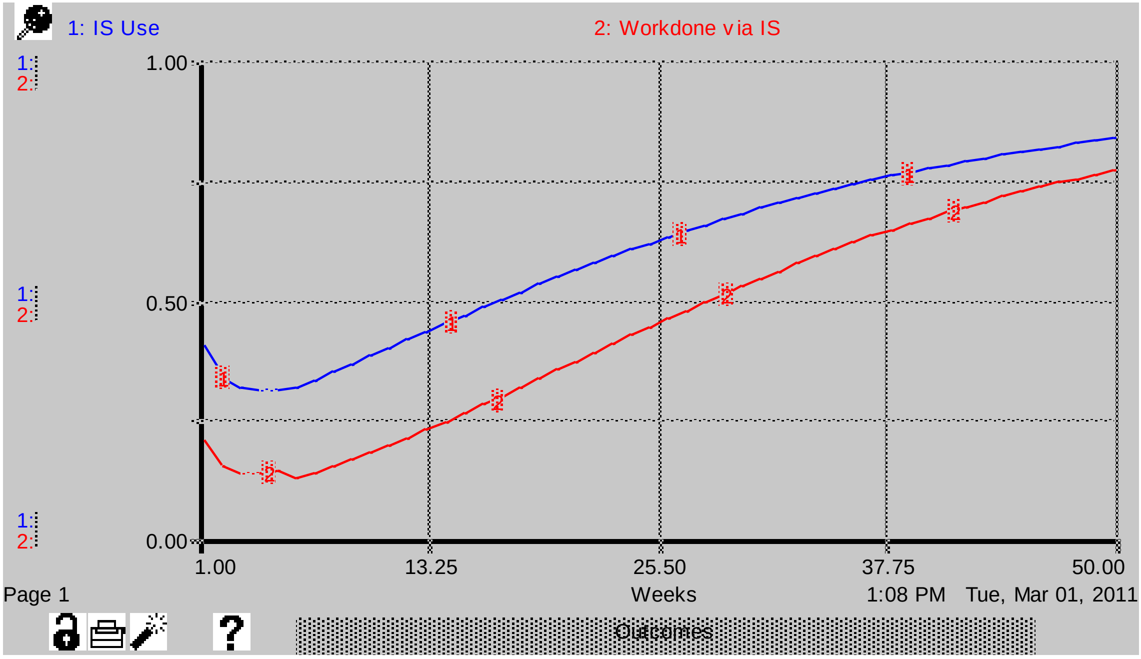


Figure 5. Scenario 3: Resource allocation of $1 each for ISM, ISS and BPS; and $1.5 for both BP and IS enhancements

What-if analysis

In addition to the results in the steady state, we were also interested in studying the transition period, such as the IS use and work done via the IS after certain amount of time, particularly the "productivity dip" even when the steady state results are high. Furthermore, we were also interested in analyzing the trade-offs between management interventions in terms of operational resources and management efforts to influence staff to become more committed to the system thus decreasing the IS use threshold. So, we ran the model for scenarios 1 and 2 by varying the total amount of resources for operational intervention (keeping the distributions the same as described above) and the IS use threshold. The charts given in Figure 6 and 7 plot the IS use and work done via IS at the end of week 10 for the different combinations of operational resources and IS use threshold.

As can be seen from the charts, the need for operational resources reduces substantially if the IS use threshold is reduced in the organization. Figure 6a for scenario 1 shows that if IS use threshold can be reduced from 0.8 to 0.2, then the same extent of IS use (about 0.6) can be achieved by needing only $1 instead of $2 for operational interventions. This indicates a trade-off for management interventions between making an effort to increase users' commitment to use the IS (thus reducing the IS use threshold) and allocating financial resources,

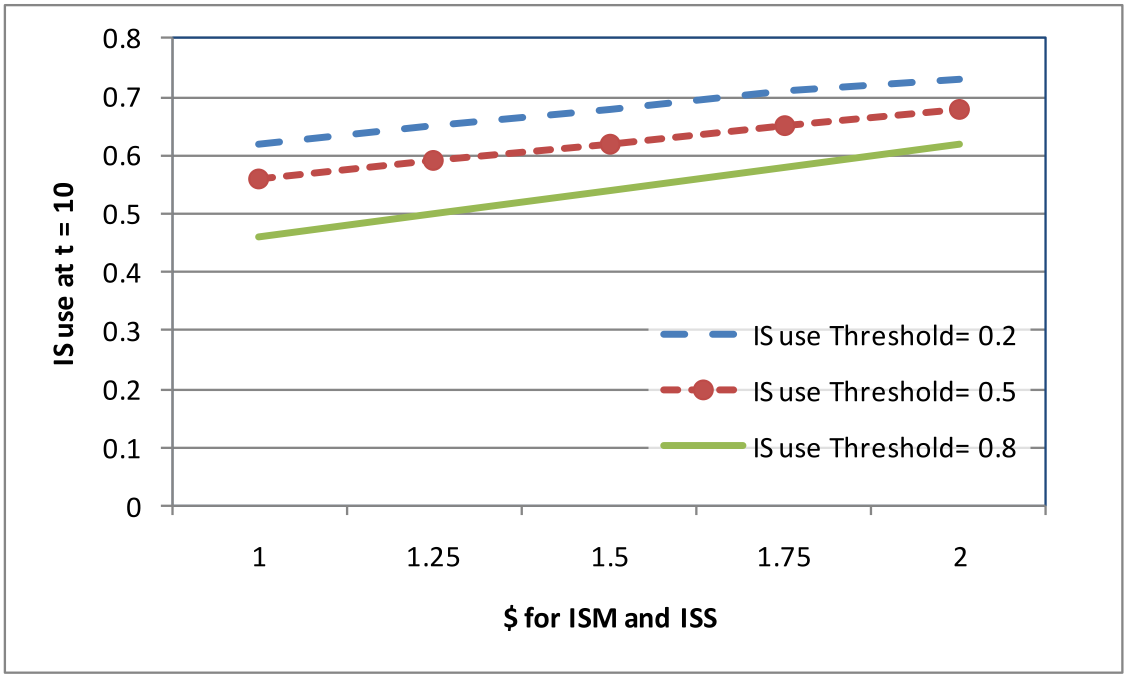


Figure 6a. Scenario 1, IS use at t = 10, as amount of resources (ISM and ISS) for operational intervention changes

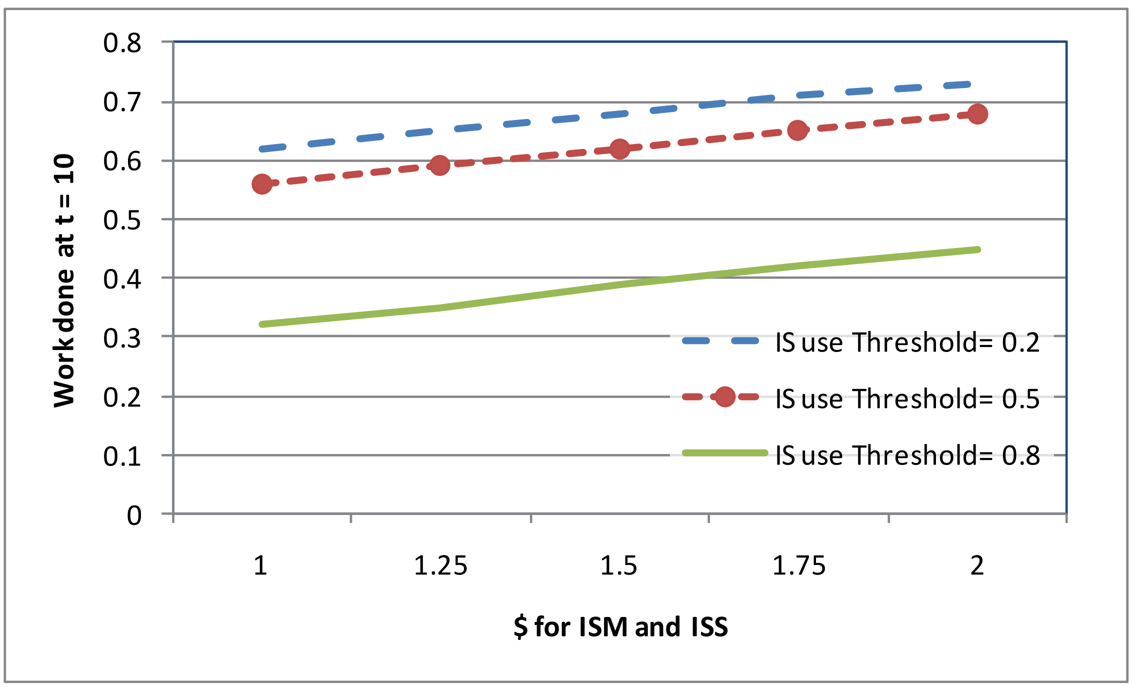


Figure 6b. Scenario 1, Work done at t = 10, as amount of resources (ISM and ISS) for operational intervention changes

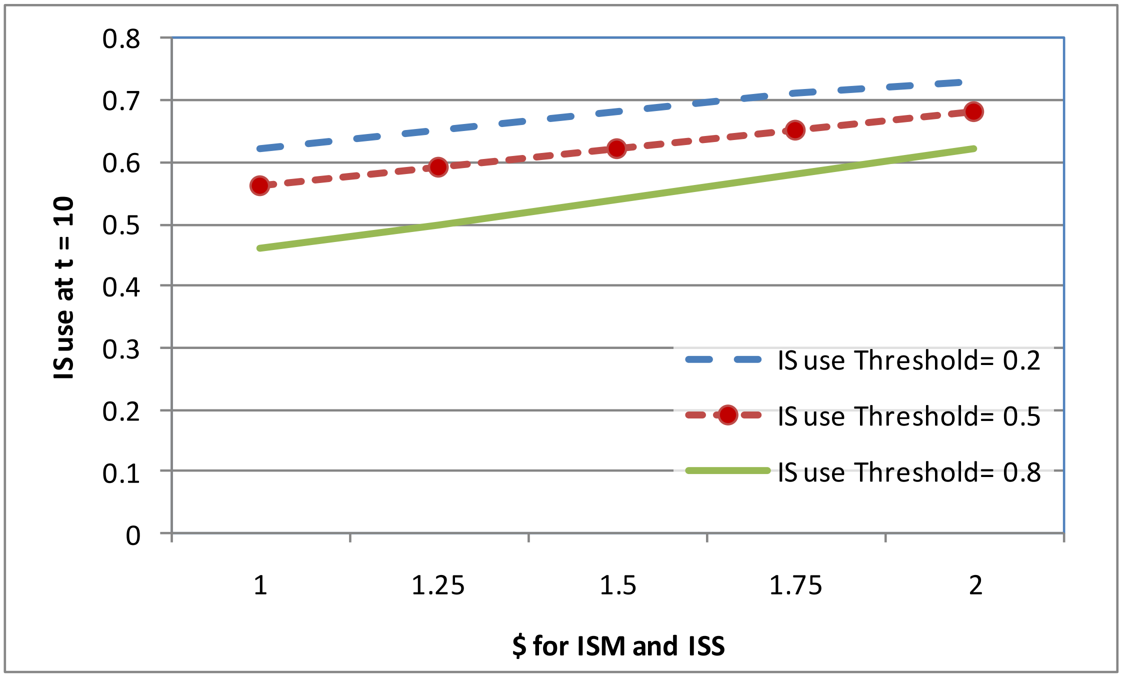


Figure 7a. Scenario 2, IS use at t = 10, as amount of resources (ISM, ISS and BPS) for operational intervention changes

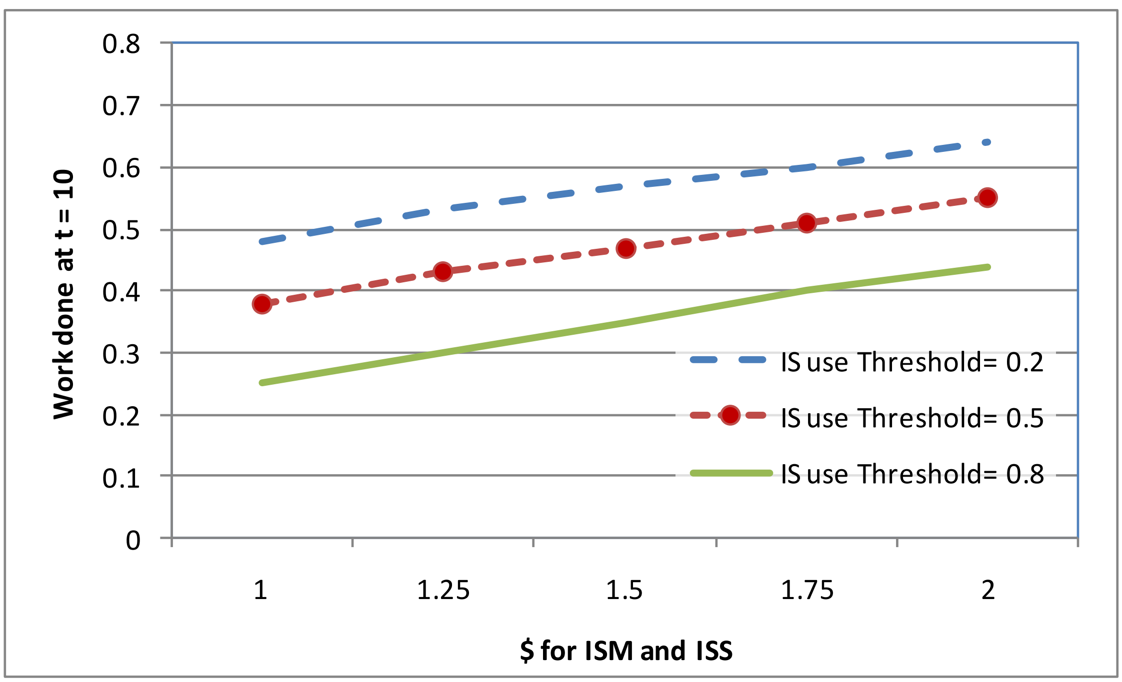


Figure 7b. Scenario 2, Work done at t = 10, as amount of resources (ISM, ISS and BPS) for operational intervention changes

Discussion

Our objective was to study how the dynamic interplay between characteristics of the users, business process requirements, enterprise IS capability and management interventions influences the IS use and the work done via IS. The system dynamics model we developed simulates that interplay in the post-installation use of enterprise information systems. We ran the model for a limited set of scenarios of initial conditions and management interventions. We would like to discuss four observations from those results. They are: (a) the model can demonstrate/corroborate the observed variability in profiles of outcomes in terms of IS use and work done via the IS including the "productivity dip"; (b) the resource allocation decisions matter, (c) resource allocations that result in higher IS use do not necessarily lead to higher work done via the IS, and (d) the users' commitment to use the IS also influences the outcome profiles.

Results from both scenarios 1 and 2 show the variability in outcomes, from steady decrease to asymptotic increase, as a result of different resource allocation decisions. Tables 1 and 2 in Attachment 2 show that if there are no management interventions in terms operational resource allocation, the IS use and work done via IS will steadily go down. The explanation is that no IS is totally error free even after extensive testing. The more the IS gets used, more bugs are found. If those bugs are not corrected, the reduction in IS use can also result in reduction in users' IS skills as per the adage "use it or lose it". Tables 1 and 2 also show a number of resource allocation decisions that result in an initial dip in IS use and work done via IS, and subsequent asymptotic increase over time. Thus the model demonstrates/corroborates the observed variability in profiles of outcomes in terms of IS use and work done via the IS including the "productivity dip".

Tables 1 and 2 in Attachment 2 also show that not only operational resources matter but their allocation decisions across IS maintenance, IS skills training and BP skills training also matter. Three allocation decisions, namely (a) all resources for IS maintenance (b) all resources for BP skills training and (c) resources equally divided among IS maintenance and BP skills training, are not useful at all and result in steadily decreasing IS use and work done via IS. The other four resource allocation decisions do show an initial dip followed by asymptotic increases in IS use and work done via IS. The results indicate that decisions on operational resource allocations do matter. The numerical results shown in Tables 1 and 2 in Attachment 2 are based on a set of plausible values of coefficients and factors that we have used in the model run for a fictitious organization. Hence the exact results will vary based on characteristics of organizations.

We studied further the four allocation decisions that showed asymptotic increase in outcomes, albeit with an initial dip. The steady state values of the outcomes are significantly different across the four decisions. Although allocating equal resources for IS maintenance and IS skills training results in higher steady state IS use (0.92 at the end of 50 weeks), the work done via IS is much larger for another decision of equal allocation of resources across IS maintenance, IS skills training and BP skills training. That implies that the most appropriate resource allocation decision will depend on where management attention is focused – on the use of IS or on the business value obtained from the IS in terms of work done via the IS. The implication is that resource allocation decision matters and that the most appropriate decision depends on management perspective.

The results from scenarios 1 and 2 also point to the importance of commitment of the users. As stated earlier, even though use of enterprise information systems is always mandated, users are not always fully committed to the use the IS. That lower commitment results in a higher threshold for IS use that is acceptable to the users. That higher IS use threshold can result in an initial dip in IS use and work done via IS. This can be seen clearly from Figures 3 and 4 where the IS use threshold is high at 0.8. While this initial dip, is not acceptable by itself, it could also lead to other consequences that would be detrimental to the enterprise. Users could get discouraged and detractors of the system would find ammunition to attack the decision to install the system. Thus it is in management's interest to avoid the initial dip as much as possible. Figures 3 and 4 also show that for a low IS use threshold of 0.2, there is no initial dip and in addition, the steady state outcomes are higher. That implies that if management is able to increase users' commitment to use the system, thus decreasing IS use threshold, it may be possible to reduce or even avoid the initial dip, the problems associated with such a dip, and also achieve higher steady state outcomes.

The what-if analysis was aimed at studying the joint influence of IS use threshold and operational resource amounts on the outcomes during the transition period. The results from that analysis, shown in Figures 6 and 7, point to a trade-off between allocation of operational resources and management making an effort to increase users' commitment to use the IS thus reducing the threshold. Lower IS use threshold requires less operational resources to achieve equivalent outcomes (IS use and work done via IS) compared to a higher threshold. This could be one way to "monetize" the management effort needed to increase the commitment of staff to use the IS thus deceasing the IS use threshold.

Results from running the model for scenario 3 are that different strategic resource allocations for BP enhancements and/or IS enhancements did not show much difference in the outcomes. That is not very informative, indicating that we need to take a closer look at the model to see if it can be refined to differentiate between such strategic allocation decisions better.

The model, presented in this paper, covers the "system" at the macro level only. The enterprise is not decomposed into its business units carrying out subsets of the business processes; the IS is not viewed for its separate functionalities; and the users are not divided by their roles/responsibilities or by their level of expertise. Furthermore, we have not carried out what-if analyses for the other coefficients / factors to see how those organization specific parameters may affect the patterns and profiles. Given these limitations, it is not yet clear if the current model could be useful at a more detailed level. Nevertheless, we believe that the model provides a first step in formalizing the complex dynamic relationships that determine the profiles of IS use and work done in the post-installation use of enterprise information systems.

Next steps

We would like to validate the model using observations from a few cases. Then, we would like to carry out sensitivity analysis to see how the factors and coefficients, which are dependent on the context of the enterprise, affect the outcomes. As stated above, we would also like to refine the model to see if it can differentiate between strategic resource allocations decisions.

References

Abdel-Hamid, Tarek K. "The economics of software quality assurance: a simulation-based case study" MIS Quarterly, 4:3 (1988), 395-411.

Abdel-Hamid, Tarek K. and Stuart E. Madnick "Lessons learned from modeling dynamics of software development" Communications of the ACM, 32:12 (1989), 1426-1455

Abdel-Hamid, Tarek K., Kishore Sengupta, and Clint Swett "The impact of goals on software project management: an experimental investigation" MIS Quarterly, 23:4 (1999), 531-555.

Akkermans, H., and K. van Helden, "Vicious and virtuous cycles in ERP implementation: a case study of interrelations between critical success factors", European Journal of Information systems, 11 (2002), 35-46.

Bagchi, Shantanu, Shivraj Kanungo, and Subhasish Dasgupta "Modeling use of enterprise resource planning systems: a path analytic study", European Journal of Information Systems, 12 (2003), 142-158.

Bhattacherjee, Anol "Understanding information systems continuance: an expectation-conformation model" MIS Quarterly, 25:3 (2001), 351-370.

Bhattacherjee, Anol, and G. Premkumar G "Understanding changes in belief and attitude towards information technology usage: A theoretical model and longitudinal test", MIS Quarterly, 28:2 (2004), 229-254.

Boudreau, M-C "Learning to Use ERP Technology: a Causal Model", Proceedings of the 36th Hawaii International Conference on System Sciences, January 6-9, 2003.

Clark, Thomas D. and Mary C Jones "An experimental analysis of the dynamic structure and behavior of managerial support systems", Systems Dynamics Review, 24:2 (2008), 215-245.

Garud, Raghu and Arun Kumaraswamy, "Vicious and virtuous circles in the management of knowledge: The case of Infosys Technologies", MIS Quarterly, 29:1 (2005), 9-33.

Gattiker, Thomas F. and Dale L. Goodhue “Software-driven changes to business processes: an empirical study of impacts of Enterprise Resource Planning (ERP) Systems at the local level”, International Journal of Production Research, 40:18 (2002), 4799-4814.

Gattiker, Thomas F. and Dale L.Goodhue “What happens after ERP implementation: Understanding the impact of inter-dependence and differentiation on plant-level outcomes”, MIS Quarterly, 29:3 (2005), 559-585.

Jasperson, Jon Sean, Pamela E Carter, and Robert W Zmud “A comprehensive conceptualization of post-adoptive behaviors associated with information technology enabled work systems”, MIS Quarterly 29:3 (2005), 525-557.

Jenkins, R. “Enterprise Resource Planning as the Trojan Horse for New Rules of Operations Management”, Creativity and Innovation Management, 10:3 (2001), 201–209.

Jones, Mary C., Robert W. Zmud, and Thomas D. Clark “ERP in Practice: A snapshot of post-installation perception and behaviors” Communications of AIS, 23:1 (2008), 437-462.

Malhotra, Yogesh and Dennis Galletta “A multidimensional commitment model of volitional systems adoption and usage behavior”, Journal of Management Information Systems, 22:1 (2005), 117-151.

Mendoza, Antonette, Jennie Carroll, and Linda Stern “Influences on continued use of an information system: a longitudinal study”, Proceedings of the 16th European Conference on Information Systems, June 9-11, 2008.

Okrent, Michael D. and Robert J. Vokurka "Process mapping in successful ERP implementations", Industrial Management & Data Systems, 104: 8 (2004), 637-643.

Orlikowski, Wanda “CASE tools as organizational change: Investigating incremental and radical changes in system development”, MIS Quarterly, 17:3 (1993), 309-340.

Schwartz, Andrew and Wynn Chin “Looking forward: Toward an understanding of the nature and definition of IT acceptance”, Journal of AIS, 8:4 (2007), 230-247.

Venkatesh, Vishwanath, Michael G Morris, Gordon B. David, and Fred D. Davis “User acceptance of information technology: Toward a unified view” MIS Quarterly, 27:3 (2003), 425-478.

Venkatesh, Viswanath, Fred D. Davis, and Michael G. Morris “Dead or alive? The development, trajectory and future of technology acceptance research”, Journal of AIS, 8:4 (2007), 267-286.

Volkoff, O., M. B. Elmes, and D. M. Strong "Enterprise systems, knowledge transfer and power users", The Journal of Strategic Information Systems, 13:4 (2004), 279-304.

Attachment 1 – Equations used in the model

```
IS_capability_gap(t) = IS_capability_gap(t - dt) + (- IScapgapdecr) * dt
INIT IS_capability_gap = .2

OUTFLOWS:
IScapgapdecr = IF ($_for_BP_enhancements * 0.1 + $_for_IS_enhancements * 0.1) >
IS_capability_gap then IS_capability_gap else ($_for_BP_enhancements * 0.1 +
$_for_IS_enhancements * 0.1)
IS_quality_known(t) = IS_quality_known(t - dt) + (ISqualincr - ISqualdecr) * dt
INIT IS_quality_known = 1

INFLOWS:
ISqualincr = ($_for_IS_maintenance * 0.05) * (1 - IS_quality_known)
OUTFLOWS:
ISqualdecr = (IS_Use * ISUsequalfactor + $_for_IS_enhancements * .2) * IS_quality_known /
TIME
Users'_IS_BP_gap(t) = Users'_IS_BP_gap(t - dt) + (UBPskilgapincr - UBPskilgapdecr) * dt
INIT Users'_IS_BP_gap = .5

INFLOWS:
UBPskilgapincr = (1 - Users'_IS_BP_gap) * ((IF IS_Use < (IS_use_treshold - 0.1) then
(IS_use_treshold - 0.1 - IS_Use) * ISUseBPskilfactor / TIME  else 0) +
$_for_BP_enhancements * 0.1)
OUTFLOWS:
UBPskilgapdecr = Users'_IS_BP_gap * ((IF IS_Use > (IS_use_treshold + 0.1) then (IS_Use -
(IS_use_treshold + 0.1)) * ISUseBPskilfactor / TIME else 0)  + $_for_BP_training * 0.05)
Users'_IS_skills_gap(t) = Users'_IS_skills_gap(t - dt) + (UISskilgapincr -
UISskilgapdecr) * dt
INIT Users'_IS_skills_gap = .5

INFLOWS:
UISskilgapincr = (1 - Users'_IS_skills_gap) * ((IF IS_Use < (IS_use_treshold - 0.1) then
(IS_use_treshold - 0.1 - IS_Use) * ISUseISskilfactor / TIME else 0) +
($_for_IS_enhancements * 0.1))
OUTFLOWS:
UISskilgapdecr = Users'_IS_skills_gap * ((IF IS_Use > (IS_use_treshold + 0.1) then
(IS_Use - (IS_use_treshold + 0.1)) * ISUseISskilfactor / TIME else 0) + $_for_IS_training
* 0.05)
$_for_BP_enhancements = 0
$_for_BP_training = 1
$_for_IS_enhancements = pulse (2,15,100)
$_for_IS_maintenance = 1
$_for_IS_training = 1
ISUseBPskilfactor = 0.5
ISUseISskilfactor = 0.5
ISUsequalfactor = .2
IS_Use = (1 - IS_capability_gap) * IS_quality_known * (1 - Users'_IS_skills_gap)
IS_use_treshold = 0.8
Workdone_via_IS = IS_Use * (1 - Users'_IS_BP_gap)
```

Attachment 2 – Summary tables of results from running the model for the three scenarios (IS use and Work done via IS are the steady state values at the end of the run for 50 weeks)

Table 1 for Scenario 1 (start IS Use 0.5, work done via IS 0.5, IS use threshold = 0.8)

Operational Resource allocations	IS Use	Work done via IS	Remarks
No interventions	0.16	0.07	Steadily downwards
$3 for IS maintenance (ISM)	0.23	0.1	Steadily downwards
$3 for IS skills training (ISTr)	0.6	0.43	Initial dip, then increase asymptotically
$3 for BP skills training (BPTr)	0.16	0.15	Steadily downwards
$1.5 each for ISM and ISTr	0.92	0.64	Initial dip, then increase asymptotically
$1.5 each for ISM and BPTr	0.22	0.21	Steadily downwards
$1.5 each for ISTr and BPTr	0.61	0.6	Initial dip, then increase asymptotically
$1 each for ISM, ISTr and BPTr	0.85	0.81	Initial dip, then increase asymptotically

For $1.5 each for ISM and ISTr

IS use threshold High (0.8)	0.92	0.64	Initial dip, then increase asymptotically
IS use threshold Medium (0.5)	0.93	0.93	Slight dip, then increase asymptotically
IS use threshold Low (0.2)	0.93	0.93	No dip, and increase asymptotically

Table 2 for Scenario 2 (start IS Use 0.5, work done via IS 0.25); For IS use threshold = 0.8

Operational Resource allocations	IS use	Work done via IS	
No interventions	0.16	0.03	Steadily downwards
$3 for IS maintenance (ISM)	0.23	0.05	Steadily downwards
$3 for IS skills training (ISTr)	0.6	0.21	Initial dip, then increase asymptotically
$3 for BP skills training (BPTr)	0.16	0.15	Steadily downwards
$1.5 each for ISM and ISTr	0.92	0.32	Initial dip, then increase asymptotically
$1.5 each for ISM and BPTr	0.22	0.2	Steadily downwards
$1.5 each for ISTr and BPTr	0.61	0.59	Initial dip, then increase asymptotically
$1 each for ISM, ISTr and BPTr	0.85	0.79	Initial dip, then increase asymptotically

$1 each for ISM, ISTr and BPTr

IS use threshold High (0.8)	0.85	0.79	Initial dip, then increase asymptotically
IS use threshold Medium (0.5)	0.87	0.84	Slight dip, then increase asymptotically
IS use threshold Low (0.2)	0.88	0.86	No dip, and increase asymptotically

Table 3 for Scenario 3 (start IS Use 0.4, work done via IS 0.2)

Operational intervention of $1 each in ISM, ISS and BPS
IS use threshold = 0.8
Strategic intervention in week 5

Strategic intervention	IS use	Work done via IS	Remarks
$3 for BP enhancements	0.85	0.78	Initial dip, then rise asymptotically
$3 for IS enhancements	0.83	0.76	Initial dip, then rise asymptotically
$1.5 for both BP and IS	0.84	0.77	Initial dip, then rise asymptotically