2005

Towards an "Optimal" Level of Information Systems Flexibility - A Conceptual Model

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TOWARDS AN “OPTIMAL” LEVEL OF INFORMATION SYSTEM FLEXIBILITY – A CONCEPTUAL MODEL

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Abstract

While insufficient flexibility of an information system to support a given business process precludes system use in certain cases, excessive flexibility can limit system usability (Silver 1991), in addition to presenting an unnecessary investment. Despite a wealth of research on flexibility and its impacts on organizations and business processes (esp. manufacturing), the value of flexibility and the price at which it comes have rarely been included into the analysis, with the result that guidelines to determine an appropriate (let alone optimal) level of flexibility of organizations, business processes or information systems have not been developed. To support decisions regarding information system flexibility, the current paper presents a conceptual model that determines the performance of a given business process during the lifetime of a supporting information system, with performance measured as cost-efficiency. The focus of the model is on the trade-off between investments in two types of flexibility: flexibility to use and flexibility to change an information system. After presenting the conceptual model, directions for further research are pointed out.

Keywords: information system flexibility, business process performance, real options postponement.

1 MOTIVATION

In order to be effective, an information system needs to be flexible and be able to accommodate a certain amount of variation of the supported business process. For example, for an electronic procurement system to allow for the processing of actual purchasing requests it needs to include a reasonable amount of product categories and approval procedures. While insufficient flexibility can limit the success of an information system by precluding its use in certain circumstances and making exception handling necessary, excessive flexibility can also limit the success of an information system, (a) by reducing usability especially for inexperienced users (Silver 1991) and increasing complexity (Soh, Sia, Boh, and Tang 2003), and (b) by requiring possibly unnecessary investments (Koste and Malhotra 1999). Despite a wealth of research on flexibility and its impacts on organizations (Aaker and Mascarenhas 1984, Eppink 1978, Evans 1991, Volberda 1997) and business processes especially manufacturing processes (Gerwin 1993, Sethi and Sethi 1991, Upton 1997a, Upton 1997b), the value of flexibility and the price at which it comes have often not been included in the analysis (Koste and Malhotra 1999) with the result that guidelines to determine an appropriate level of flexibility of an information system to support a given business process have not been developed.

The objective of the current paper is to contribute to business process management by providing guidelines regarding the management of flexibility of an information system to support given business process. To help improve the effectiveness of investments in information systems we attempt to determine a level of information system flexibility that balances variability and rigidness (Silver 1991).

The research study is motivated by the advent of modern information systems and technologies, such as component-based and service-oriented software architectures, autonomous computing concepts (Horn 2001), web services, and mobile applications that promise to be more flexible than the legacy, mainframe- and client/server-based systems they are meant to replace (Whiting 2003, Duncan 1995).

In the following, we first focus on the flexibility of information systems, in particular the flexibility to use and the flexibility to change an information system. Second, we present a conceptual model to help determine the long-term efficiency of business processes, based on decisions regarding investments in the flexibility of supporting information systems. The focus of the model is on the trade-off between the two types of information system flexibility. Process performance is modelled as cost efficiency during the lifetime of the information system. After presenting the conceptual model, directions for further research are pointed out.

2 FLEXIBILITY OF INFORMATION SYSTEMS

In the research area of manufacturing, research studies have shown that dedicated, single-purpose machines typically operate at lower costs than multi-purpose machines and processes (i.e., single-purpose machines exhibit greater efficiency), yet single-purpuse machines provide less flexibility and there is a chance that not all requirements are met (Duimering, Safayeni, and Purdy 1993). For the research area of information systems, Silver (1991) showed that both, an extremely flexible and an extremely restrictive (=inflexible) design of a decision support system can inhibit system use and with it system success. While the extremely restrictive decision support system evidently limits the user to only certain types of procedures and precludes the use of others, the extremely flexible system can discourage usage by being too overwhelming for the inexperienced user. Soh, Sia, Boh, and Tang (2003) pointed out that increasing flexibility of an enterprise resource planning system leads to an increase in complexity.

Currently, there is not much guidance on how to manage the flexibility of an information system, let alone determine the optimal level of information systems flexibility in order to support a given business process. Our study is based on the assumption that similar to manufacturing technology, information systems in support of a given business process can exhibit different levels of operating efficiency and of flexibility. We propose that similar to the management of manufacturing technology, information systems managers need to strike a balance between efficiency effects from automation provided by an information system, and the flexibility required to adequately perform a given business process over time, given that flexibility generally comes at the price of complexity and additional required investment efforts.

With Hanseth, Monteiro, and Hatling (1996), we suggest to include two types of flexibility into the analysis: (1) the built-in flexibility to use that an information system provides before major changes have to be made; and (2) the flexibility to change a given system, related to the notion of information technology infrastructure, and e.g., provided by a modular architecture built on standard interfaces.

2.1 Built-In Flexibility to Use an Information System

Building on Sethi and Sethi's (1990) general understanding of manufacturing flexibility as being determined by the range of possibilities that are provided by a given system until a "major change" is required (p. 296), we define the built-in flexibility to use an information system as the range of possibilities that is provided by an information system until a "major change" is required. For example, the flexibility to use an electronic procurement system includes the range of different products and procurement procedures that is built into the system.

To conceptualize built-in flexibility to use an information system, we build on Soh, Sia and Tay-Yap (2000) who, in a research study of structural misfits of enterprise resource planning systems and organizational requirements, identified three broad categories as sources for misfits: data, including data format and relationships among entities, function, including processing procedures, and output, including presentation format and information content. Focussing on information system features that are related to the use of an information system in terms of scope, to be determined by system designers and project managers, we include the processing capacity of an information system into our analysis as a fourth construct besides functionality, database, and user interface:

- *Functionality* refers to the different features a system provides the user with, such as the range of procurement procedures covered by an electronic procurement system, the range of functional modules included in an enterprise resource planning system, the different types of interactions between an organization and its business partners included in an inter-organizational system (e.g., EDI-messages and RosettaNet-PIPs), and the different models and analysis techniques that are provided by a decision support system (Silver 1991)
- The scope of the *database* underlying the system refers, for example, to the number of product categories that can be purchased through the catalog of an electronic procurement system, and the number of reports and analyses contained in a data warehouse.
- *User interface* refers to the different methods an information system provides to a user to interact with it, and includes the number and type of access channels that are available, including personal computer desktop, and mobile access, as well as soft factors, such as the range of input schemes and output presentation formats.
- *Processing capacity* refers for example to the number of users an information system can accommodate concurrently, and the number of transactions and user requests an information system can process without major performance losses.

Following the initial design and implementation of an information system, the resulting built-in flexibility to use determines the range of real-world situations that can reasonably be handled with the information system, as well as the efforts that are required to utilize the system on a day-to-day basis (operational costs). In cases where the circumstances of a process preclude the usage of the information system to perform a certain task, the organization has to resort to exception handling, e.g., manual and paper-based processing of a purchase order and the "traditional" (non-electronic) exchange of data and information with a business partner.

2.2 Flexibility of an Information System to Change

Besides the decision regarding the overall built-in flexibility to use an information system, system designers and project managers also face a decision regarding the effort required to change a given information system after its initial implementation. Choices range from systems that cannot be expanded or changed in any way (off-the-shelf, turnkey systems), to arrangements that provide many opportunities for expansion and change after the initial system has been put to use. The general idea of the flexibility of an information system to change is quite closely related to the concept of (information system) infrastructure.

A number of researchers have studied the concept of information technology infrastructures, referring to general-purpose information technology resources that are shared throughout the organization, that are of long-term use, and that provide a basis for more specific applications (Byrd and Turner 2000, Weill 1993). Information technology infrastructure is relevant as an enabler of flexibility because it provides the basis for a wide range of business processes and strategies (Weill 1993). The focus has been on identifying relevant information technology components, such as platform technology (hardware, operating systems), network and telecommunications technology, data, and core applications (Duncan 1995); and infrastructure management strategies, including skills management and standardization, that can ensure flexibility (Duncan 1995, Weill 1993).

To operationalize infrastructure flexibility to change an information system, we build on the results of Byrd and Turner's (2000) careful approach to measurement development. Byrd and Turner (2000) identified three factors as relevant to describe the flexibility of information technology infrastructures: the flexibility of the information technology personnel, as manifested in a variety of skills and attitudes of the information technology *staff*; the *integration* of data and functionality, as provided by an open network architecture, a multitude of interfaces with transparent access to platforms and applications and compatibility of applications across platforms; and *modularity*, as provided by the use of re-usable software modules, vendor-independent database connectivity, and object-oriented development tools.

We view investments in flexibility to change an information system as investments that are made in addition to investments in built-in flexibility to use the information system. Flexibility to change an information system determines the effort later on required to add functionality to the current information system, to extend the database, to augment the user interface, and to add processing capacity in order to respond to unanticipated process situations. As will be pointed out in more detail below, flexibility to change is closely related to the concepts of real options and postponement, in the sense that this type of flexibility adds to the investment effort today by providing an option to be exercised in the future.

3 A MODEL TO ASSESS LONG-TERM PROCESS PERFORMANCE

Since earlier research on information system flexibility has provided little guidance to answer questions such as how much and what kind of flexibility should be included in a system to maximize performance, we now present a conceptual model as a starting point to develop a practical tool to support decisions regarding the flexibility of information systems. The conceptual model is based on the general idea of real options theory and postponement strategies, as we feel that these approaches can be applied well to help evaluate information system investment decisions.

Researchers have identified many factors to determine the performance of business processes, including: efficiency, effectiveness, customer satisfaction, bottom line impact, and shareholder value (Hammer and Champy 1993). In order to avoid over-complication of our model from dynamically changing processes, we focus our attention on a *given* process, for example purchasing, and measure performance as process efficiency over time. We consequently assume the target process outcome to remain steady, in particular in terms of quality and processing time. In cases where a process cannot be performed in time and where the quality of outcome is not adequate, we assume additional operational costs as a penalty for late and for poor performance. For a targeted process outcome, process efficiency is then inversely related to the effort (cost) required to perform the process over a certain period of time. The overall effort includes the initial investments in the information system (built-in flexibility to use, plus infrastructure flexibility to change), and the ongoing costs related with the daily use of the information system (operational costs, and exception handling costs), plus any additional investments required to actually perform system changes, all through the lifetime of the information system.

3.1 Evaluation: Real Option Valuation and Postponement Strategy

The notion of evaluating infrastructure flexibility to change an information system is closely related to two concepts that have been developed outside of the research area of information systems: real option valuation and postponement strategy.

Copeland and Keenan (1998) defined an option as “the right, but not the obligation to buy (or sell) an asset at some point in time within a predetermined period of time for a predetermined price.” Originally, mathematical techniques have been developed to evaluate financial options and to calculate a price “for the value of the flexibility to exercise a given right, such as that of being able to buy the stock of a company at a fixed price” (Kogut and Kulatilaka 1994, p. 53). The real options approach to risk management and investment decision making (Amram and Kulatilaka 1999) has been applied in the context of information systems, such as the strategic management of information technology investments (Kambil, Henderson, and Mohsenzadeh 1993), the evaluation of information technology project investments (Benaroch and Kauffman 1999), investments in information technology platform innovations (Fichman 2004), the development of guidelines for software development (Sullivan, Chalasani, Jha and Sazawal 1999), and supply chain management in the high technology sector (Billington, Johnson, and Triantis 2002).

Closely related to the real option valuation approach is the strategy of postponement, a form of strategic management that has was initially presented by scholars of marketing for the management of distribution channels (Bucklin 1965), and later extended to the management of manufacturing processes (Lee and Tang 1997) and supply chains (Anand and Mendelson 1998). Postponement has been proposed as a strategy to improve the management of variability of supply and demand in situations of uncertainty. In general, a strategy of postponement seeks to delay certain decisions (e.g., product differentiation) during the course of a business process (e.g., manufacturing and distribution) assuming that information that becomes available closer to the date of the actual sale of the product to an end-customer will improve the quality of the decision making.

Compared to scholars of option approaches with a general background in finance, scholars of postponement strategies tend evaluate postponement strategies with techniques developed for management science and operations research (e.g., Lee and Tang, 1997) and often focus on the identification and description of different types of postponement strategies, e.g., standardization, modular design, process restructuring, including the interdependencies in the supply chain, rather than on the numerical evaluation and comparison of several strategies. Following its application to the management of distribution channels and supply chains, the idea of postponement has recently been applied to electronic brokering (Robinson and Elofson 2000) and demand management (Iyer, Deshpande, and Wu 2003).

3.2 Conceptual model

By depicting several cost factors and how they occur over time, the conceptual model presented in the following, serves as a basis to support decisions regarding the allocation of investments in the flexibility to change versus investments in the built-in flexibility to use an information system. At this point, we outline the general idea and concept, rather than determine actual values based on the specifics of options theory (Copeland and Keenan 1998, see also Kogut and Kulatilaka 1994 and Fichman 2004 for discussions regarding the difficulties of valuating real options).

Figure 1 depicts the proposed conceptual model pointing out five cost factors. We assume that in period t_0, a decision is made regarding the allocation of an investment budget to (1) achieve a certain level of built-in flexibility of an information system in terms of functionality, data base, user interface and processing capacity (cost 1), and to (2) provide for a certain level of flexibility to change the system later on, as manifested in a modular infrastructure with the intent to allow for expansion in the future, training for staff that is capable of making significant changes to the information system, and an integration that makes the information system generally conducive to the development of new applications (cost 2). In the context of the model, the investment in flexibility to change is optional and, thus, has the character of a real option and postponement strategy that can be exercised one time or even several times in the future. Investments in built-in flexibility encompass all efforts required to set up the information system for immediate use.

Following the initial investments in period t_0, process occurrences during the periods of t_1 to t_T demand the use of the information system on an ongoing basis. For each process occurrence (e.g., purchasing request), it needs to be determined whether the information system can be applied to perform the tasks at hand (e.g., is the appropriate type of purchasing procedure implemented in the electronic procurement system?) (cost 3), or whether the system is not suited to perform the task. In cases where the system cannot be used, a decision is to be made regarding an alternate method to handle the task (e.g., manual processing, cost 5) and regarding additional investments to actually change the information system to meet the process requirements, in other words, to exercise the option (cost 4). Examples of information system changes include the implementation of additional software modules, extension of the underlying database, the deployment of additional access channels, e.g., to interact with customers online, and additional process capacities, e.g., with a new application server.

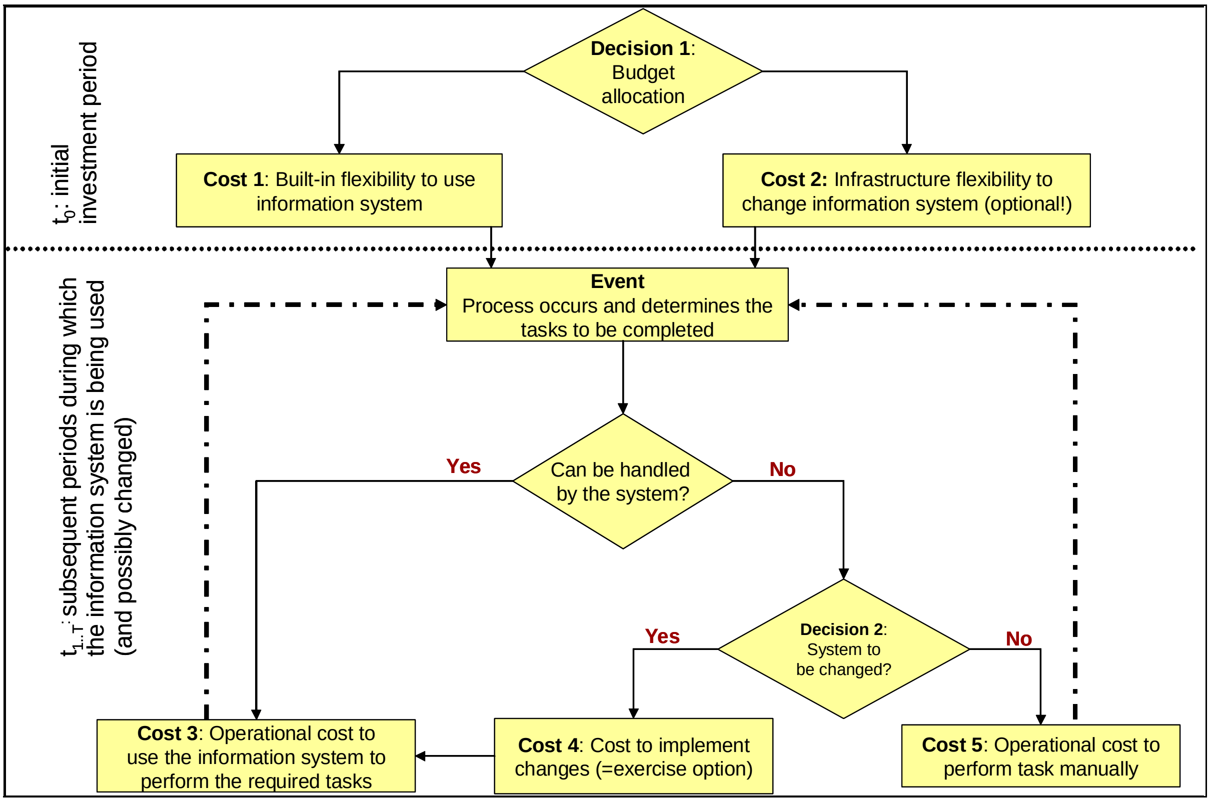

Figure 1 - Conceptual model to assess the overall cost of an information system to support a given business process over time; taking into account investments in two types of flexibility (flexibility to change and flexibility to use)

It is assumed that upfront investments into a flexible information system infrastructure will limit the efforts required later to change the system in cases where the built-in flexibility of the system is insufficient to meet actual requirements. Overall process performance (=efficiency) is then determined by the sum of all five cost factors (Cost 1 to Cost 5) during the periods of t_0 to t_T.

4 OUTLOOK

The objective of the model is to provide general guidelines regarding the system setup (cost 1 and 2) such that the operational process handling costs (cost 3 and cost 5) and change costs (cost 4) are minimized over time for a given process outcome. In general, the investment in the built-in flexibility of the information system (cost 1) determines: (1) whether the system can handle a given process occurrence and (2) the cost required to use the system in its intended, regular way (cost 3) (Figure 2). Similarly, the investment in information system infrastructure flexibility (cost 2) determines the actual cost to change the system (cost 4). Process characteristics determine operational costs to use the information and to perform the tasks at hand outside of the information system (cost 5).

As next steps, we suggest to develop end empirically test a set of propositions to assess the impact of business process characteristics on operational costs. We also suggest applying analytic techniques, from the research areas of operations research/management science and options theory to evaluate the conceptual model and to improve our understanding of the suggested relationships. Furthermore, we suggest applying the model to evaluate the contribution to information system flexibility of recent information system innovations, such as web services and service-oriented architectures.

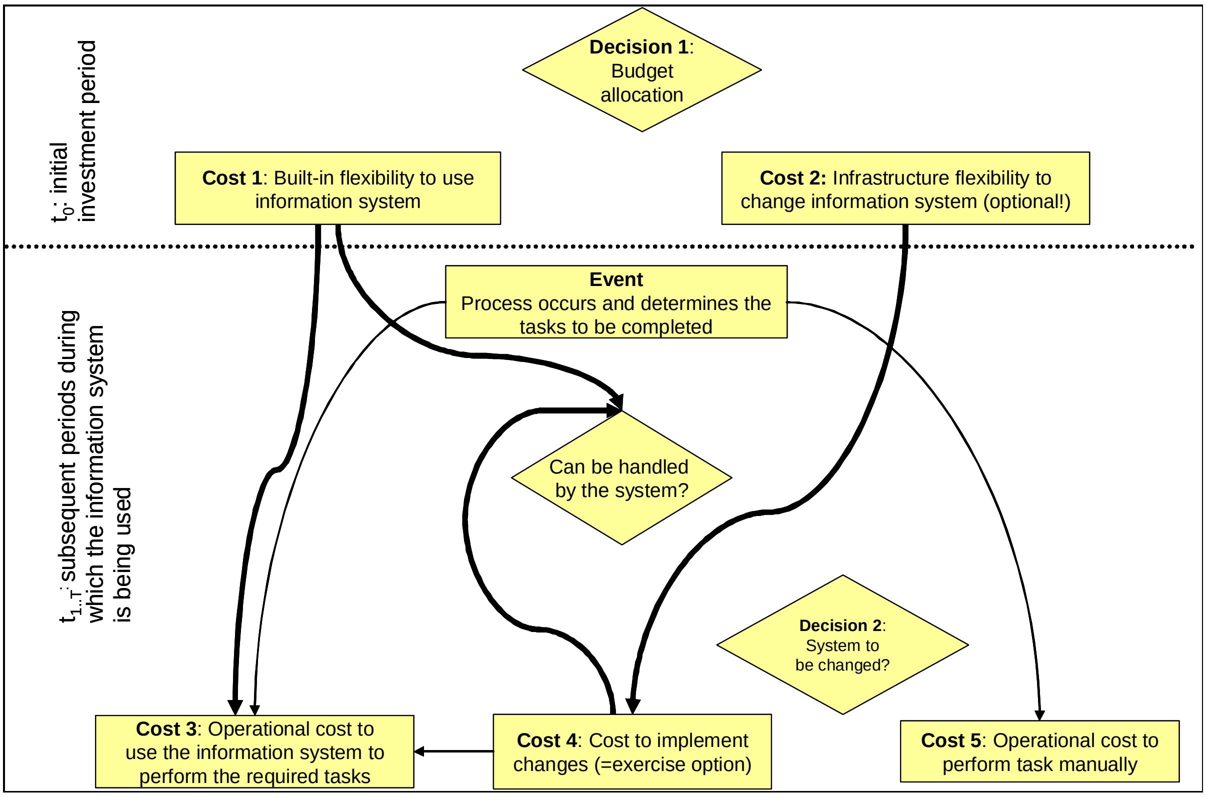

Figure 2: Suggested impact relationships between model constructs

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