Information Systems Frontiers 5:3, 289–301, 2003

Information Technology Investments: Characteristics, Choices, Market Risk and Value

Brian L. Dos Santos*
Department of Computer Information Systems, College of Business & Public Administration, University of Louisville, Louisville, KY 40292, USA
E-mail: briandossantos@iitbombay.org

Abstract. *The decisions confronting information technology (IT) managers have changed a great deal since the early 1970s. The key decisions three decades ago were related to the management of application development projects and operations centers. Today, the key decisions are quite different. What level of service should the firm provide end-users? Should IT services, development projects and the ownership and management of operations centers be outsourced? IT investments attempt to satisfy specific needs. Because of environmental differences and differences in the cost structure and benefits of alternative ways in which these needs can be met, the answers to these questions may differ across firms. Modern financial analysis can provide insights to help managers deal with many of the problems they currently face. We use modern financial theory to show how the value of IT investments can be affected by some of the choices made by managers. We show how the market risk of demand and the market risk of costs affect the market risk and value of IT investments. We consider three types of investment decisions: outsourcing versus in-house services; investments in interorganizational systems; and determining the optimal level of IT services that should be provided. Our analysis indicates that: (1) as the market risk of demand for operations decreases, firms are less likely to outsource operations; (2) the value of an investment in an interorganizational system increases as the market risk of costs increases; and (3) the optimal level of user service is inversely related to service demand risk and is directly related to the market risk of service costs.*

1. Introduction

Firms are spending billions of dollars on computer systems. However, there have been claims that firms fail to benefit from these investments and suggestions that firms are making poor information technology (IT) investment decisions (Brynjolfsson and Hitt, 1996; Dos Santos, Peffers and Mauer, 1993; Benaroch and Kauffman, 1999). Information technology investment decisions are often based on intuition, fear and following what other firms have done. Only infrequently are these decisions based on financial analysis (Dos Santos, 1991; Keen, 1981). Although ex ante financial analysis of IT investments presents problems that have been discussed by many authors (Kauffman and Kriebel, 1988; Strassman, 1988; DeLone and McLean, 1992), such analysis can provide useful insights to managers faced with investment choices.

The key problems facing IT managers have changed over time. Thirty years ago, key problems faced by IT managers stemmed from the management of development projects and operations centers. Today, the key decisions are quite different. What level of service should the firm provide end-users? Should IT services, development projects and the ownership and management of operations centers be outsourced? IT investments attempt to satisfy specific needs. Because firms face different environments and the cost structure and benefits of the investment choices available to firms differ, the answers to such questions may differ across firms.

Widespread adoption of Internet standards is making it easier for firms to develop interorganizational systems. Today, systems that link a firm to its customers and suppliers are fairly common. Firms investing in interorganizational systems are faced with many decisions that affect the cost and benefit structures of these systems. For example, firms must decide whether charges for these systems are based on use, a fixed fee, or whether charges are built into the price of the goods

*I would like to thank D.C. Mauer for his help on key aspects of this paper.

and services provided. These decisions affect the cost structure and benefits of the system and thereby affect the market risk and value of the system. Market risk is the risk to a project's returns that result from adverse movements in the level or volatility of markets. Investors cannot eliminate market risks by holding a diversified portfolio. The market risk of an investment should be reflected in the rate used to discount cash flows from the investment. Hence, market risks affect the projected value of an investment. Managers must understand how alternative ways of meeting needs affect the market risk and value of a system in order to make sound investment decisions.

An increasingly important IT management decision involves determination of the level of IT services that the firm must provide. For example, IT services aimed at educating end-users and helping them deal with problems that they encounter are important, making it necessary to determine the level of support for these services. The optimal service level is affected by the characteristics of a firm's products and services, and its operations. The nature of a firm's products (or services) may determine how demand for (i.e., use of) these support services is affected by general economic conditions. The sales of some products are more sensitive to economic conditions than are others, and this sensitivity can affect the demand for IT services. Other service-related decisions also require such consideration. For example, how should priorities be set for different groups of users of a centralized resource or a network environment?

We use modern finance theory to show how different choices available to managers making certain IT investment decisions affect the market risk and value of these investments. Our analysis focuses on three different IT investment decisions. We begin our analysis with a decision involving a choice between outsourcing the operations function and housing this function within the firm. We show that outsourcing the operations function is a more viable option as the market risk of demand for the services provided by the operations function increases. Next, we consider some of the issues that must be addressed when developing an interorganizational system. Firms that are developing an interorganizational system have to make many decisions during the development and implementation phases that affect the cost structure and benefits of the system. The variable costs and benefits if such systems may not be related to demand (i.e., use). We show that the value of such systems increases as the market risk of variable costs of the system increase. Finally, we consider service level decisions. We show that the optimal service level is inversely related to demand risk and directly related to the market risk of periodic fixed costs.

The paper is organized as follows: Section 2 provides a very brief characterization of related research and provides a discussion of different types of business risk as it relates to IT investment decisions. In Section 3 we develop, analyze and interpret models for three types of IT investment decisions. A brief summary and conclusions is presented in Section 4.

2. Background

Ex ante analysis of IT investments has been studied for over two decades by information system (IS) practitioners and academics (King and Schrems, 1978; Keen, 1981; Dos Santos, 1991; Benaroch and Kauffman, 1999; Campbell, 2002). The problems encountered when trying to determine the value of IT investments are widely discussed in the literature (Keen, 1981; Benaroch and Kauffman, 1999; Brynjolfsson, 1994). The standard method to evaluate potential corporate investments is discounted cash flow (DCF) analysis. DCF analysis determines the value of an investment by discounting the expected value of each period's cash flow by a risk-adjusted discount rate. To use DCF, it is necessary to obtain unbiased estimates of the expected cash flows attributable to the investment (project) and a discount rate that adjusts for the market risk of the project. Recently, many authors have suggested that real options analysis may be a better way to evaluate potential IT investments if the current investment could provide significant investment opportunities in the future and these future investment opportunities can be identified in advance (Dos Santos, 1991; Kambil, Henderson, and Mohsenzadeh, 1993; Benaroch and Kauffman, 2000; Campbell, 2002). Many IT investments, however, do not meet these conditions. Our experience at two very large firms in the United States suggests that many firms require DCF analysis for IT investments.

The analysis in this paper is based on the DCF approach. The cash flows from IT projects are affected by numerous factors: the quality of the system, conversion effectiveness, economic conditions, interest rates and actions taken by the firm and its competitors. These factors make the costs and benefits of a project risky. IT project risks are of two types: *market risks* and *unique risks*. Market risks stem from the fact that there are economy-wide perils that threaten all businesses. For example, government regulations, general economic activity and the events of September 11th affect cash flows of all businesses to some extent. Market risk is the risk to a project's financial condition resulting from adverse movements in the level or volatility of markets. Market risks are not directly related to a specific project; yet they affect a project's cash flows. Unique risks include *project-specific* risks that are unique to the project, and *firm-specific* risks that are unique to the firm or the industry.

The information systems (IS) literature has primarily focused on project-specific risks, for example, the risks emanating from uncertainties in the development, implementation and use of the system are project-specific risks (Kambil, Henderson, and Mohsenzadeh, 1993; Mukhopadhyay, Barua, and Kriebel, 1995). Will the system be completed on time, as budgeted and with the features that are anticipated when the investment decision is made? Will the completed system be as helpful to users as anticipated and will it be as useful as expected? Risks that affect completion of the development effort, features that will be available and usefulness of the system to users are primarily a function of the characteristics of the project, individuals involved in the development effort, end users and methods used to develop the system. Although project-specific risks can be high for many IT investments, they are of no concern to a shareholder who holds a diversified portfolio of investments. Indeed, one of the central tenets of modern finance theory is that investors will not require that a discount rate for a project contain a premium for project-specific risks. Project-specific risks are accounted for in estimates of project value by adjusting a project's cash flows for the risk involved. In general, the greater the project-specific risks that reduce future benefits and/or increase cost, the lower the estimate of future expected cash flows.

Other IT investment risks are specific to a firm. For example, the actions taken by a firm in the future can affect the costs or benefits of a project. Consider the situation where a firm decides to increase promotion of its products after an IT project that reduces order-processing costs has been developed and is in use. As a result of the promotion, there may be an increase in orders, which would lead to an increase in the cash flow from the IT project. Other unique risks are industry related. For example, the actions taken by competitors may affect a project's cash flow, or prices of certain commodities may affect cash flow as a result of their impact on the prices of the firm's products. Risks that are firm or industry specific also can be eliminated by investors through portfolio diversification and should not affect the discount rate for a project. These risks should be reflected in estimates of the project's cash flows.

Although market risks affect the costs and benefits of IT projects, they have received little attention in the IT investment valuation literature (Dos Santos, 1991). Market risks, to varying degrees, influence the benefits and costs of all investments. For example, fluctuations in economic activity will generally affect the costs and benefits of a project. This is painfully evident right now; for many firms, the return on recently completed IT investments has been negatively affected by the downturn in the economy. Consider for example, a firm that recently invested in an information system that was expected to reduce order-processing costs. The number of orders that the system processes drives the benefits of this system. The number of orders the firm receives may be negatively affected by the downturn in the economy. An expanding economy may lead to an increase in sales and thereby increase the value of such an investment. The number of orders processed may be larger when the economy is growing fast and smaller when the economy is shrinking. Cash flows from such an IT investment will have a positive covariance with the return on the market. As such, the discount rate for the IT investment should reflect this risk. Modern finance theory suggests that projects with cash flows that co-vary with general market conditions require a higher discount rate than projects that are less sensitive to such conditions.

The underlying question addressed here is: how do the decisions that are made during the pre-production stages (i.e., before the system is in use) of a project affect its value? To answer this question, we need to determine how the alternatives that are available affect the market risk of the project and the value of the investment. In the next section, we develop models that allow us to determine how development and implementation decisions and project characteristics affect market risk and the value of the investment for three different types of IT investment decisions.

3. *Project Risk and Value*

The underlying assumptions for our analysis are that the firm making the investment has publicly traded shares and that managers seek to make investments that will increase the market value of the firm.[1] The models developed here are single period, discrete time models that relate project risk and value to the market risk of demand (or costs) for the system. More elaborate, continuous time models provide the same insights while greatly complicating the presentation.

3.1. Outsourcing versus in-house service

Fifteen years ago, Malone, Yates, and Benjamin, 1987 predicted that there would be an increase in outsourcing due to rapid decreases in transaction costs. Outsourcing consultants Michael F. Corbett and Associates of Hyde Park, N.Y. estimate that U.S. firms spent \$100 billion on outsourced services in 1996, 40% of that for information technology services. Due to its increasing importance, IT outsourcing has been widely studied (e.g., Chaudhury, Nam, and Rao, 1995; Lacity and Hirschheim, 1993; Lee and Kim, 1999; Nam et al., 1996). For some time now, IT managers have considered outsourcing at least some IT activities (Loh and Venkatraman, 1992). IT activities that are outsourced include: computer operations, end-user support, new systems development and system maintenance. There can be a considerable difference in the cost structures of activities that are outsourced, when compared to similar activities performed within the firm. For example, outsourcing the IT operations function results in a very different cost structure compared to in-house operations. In-house operations require large periodic fixed costs (labor, equipment, etc.) with relatively small variable costs. Short-term outsourcing contracts have smaller front-end costs and periodic fixed costs and larger variable costs (Pastore, 1993). Differences in the cost structures of outsourcing and in-house services, and differences in the use of these services by the firm, determine whether a firm should outsource its operations. Here, we show how these differences affect project risk and investment value.

Consider a firm that is faced with a choice between outsourcing its operations function and managing the function in-house. The operations function is responsible for all the activities necessary to enable the systems currently in use by the firm to operate as intended.

We assume the following:

- The system will be used for one period. There is no limit to the length of the period. At the beginning of the period the systems are available for use and demand for services provided by the operations function is determined at the end of the period.
- Periodic user demand for the services provided by the operations function, $\tilde{U}$, is stochastic with mean $\bar{U}$ and variance σ_U^2. The periodic cash flows are determined by demand for these services, the benefits derived from use of these services and the periodic costs incurred to satisfy this demand. Demand is assumed to be stochastic, since it depends on demand for the firm's outputs, the actions taken by the firm's competitors and other factors discussed earlier.
- There are zero taxes and the project is equity financed.

In the case where the operations function is outsourced, there is a variable cost, C, determined by the amount of work performed by the firm providing the service and a periodic fixed payment, F_1, that the firm must pay regardless of the amount of work that is done by the service firm. When the operations function is managed in-house, there is a periodic fixed cost, $F_2\,(>F_1)$, and a variable cost, $\gamma C, \gamma \in (0, 1)$. When operations are managed in-house, periodic fixed costs include personnel and equipment cost, and any other recurring fixed costs. In this example, the variable cost for in-house service is lower than that charged by the firm providing the outsourcing service, whereas the fixed cost is higher. Similar decisions are involved when outsourcing other IT services. A few years ago, General Electric's Appliance division decided to outsource all application maintenance activities to two firms. In so doing, they substituted a large periodic fixed cost (for employees) and a small variable cost when maintenance was done in-house, for a small fixed cost (for training the consulting firm's employees so that they could provide the service) and a large variable cost that was determined by the amount of work done by the firms that are responsible for maintenance.

For simplicity, we assume that the two alternatives are identical in terms of the service provided, i.e., the benefits (B) are the same.[2] If the operations function is outsourced (alternative no. 1), the end-of-period cash flow is

$$\tilde{X}_1 = (B - C)\tilde{U} - F_1. \qquad (1)$$

In (1), we assume that the periodic cash flows from this operation ($\tilde{X}_1$) are determined by stochastic demand for the service ($\tilde{U}$), the benefits (B), periodic variable costs (C) and periodic fixed cost (F_1). If the operations function is managed in-house (alternative no. 2), the end-of-period cash flow is

$$\tilde{X}_2 = (B - \gamma C)\tilde{U} - F_2, \quad 0 < \gamma < 1 \quad \text{and} \quad F_2 > F_1. \tag{2}$$

Therefore, the risk-adjusted expected present value of the cash flow from alternative no. 1, $PV(\tilde{X}_1)$, is

$$PV(\tilde{X}_1) = \frac{(B - C)\bar{U} - F_1}{1 + \rho_{X_1}}. \tag{3}$$

The numerator on the right hand side of (3) is the expected value of $\tilde{X}_1$, and ρ_{X_1} is the market risk-adjusted discount rate for the project. The net present value (NPV) of the project is $PV(\tilde{X}_1)$, less the initial investment.[3]

The discount rate, ρ_{X_1}, is the equilibrium expected rate of return on securities with an equivalent market risk to the project. To determine how demand for the system affects the market risk of the project, we use the definition of beta to derive an expression for the beta of the project, β_{X_1}. The project beta is a measure of the undiversifiable risk of the project, and is a key determinant of the risk-adjusted discount rate (ρ_{X_1}) for the project.

The project's uncertain rate of return, $\tilde{r}_{X_1}$, is

$$\tilde{r}_{X_1} = \frac{\tilde{X}_1}{PV(\tilde{X}_1)} - 1. \tag{4}$$

Substituting the expression for $\tilde{X}_1$ from (1) into (4), we have

$$\tilde{r}_{X_1} = \frac{(B - C)\tilde{U} - F_1}{PV(\tilde{X}_1)} - 1. \tag{5}$$

The market or undiversifiable risk of the project, measured by β_X, is given by:

$$\beta_{X_1} = \frac{\text{Cov}(\tilde{r}_{X_1}, \tilde{r}_M)}{\sigma^2(\tilde{r}_M)}, \tag{6}$$

where $\tilde{r}_M$ is the rate of return on a portfolio comprised of all stocks in the market, i.e., the "market portfolio," and $\sigma\,(\tilde{r}_M)$ is the variance of the market portfolio's return. The covariance measures the extent to which the rate of return on the project varies with the rate of return on the market portfolio. Substituting (5) into (6) and simplifying, we have

$$\beta_{X_1} = \frac{(B - C)}{PV(\tilde{X}_1)} \frac{\text{Cov}(\tilde{U}, \tilde{r}_M)}{\sigma^2(\tilde{r}_M)} = \frac{(B - C)}{PV(\tilde{X}_1)}\beta_U, \tag{7}$$

where β_U is the market risk of demand, a measure of the degree to which demand (i.e., use) for the system fluctuates with returns on the market portfolio. For example, how does demand for the services that the operations function provides, fluctuate with a composite market measure such as the Wilshire 5000 index. Since $((B - C)/PV(\tilde{X}_1))$ should be positive, the project's beta is directly related to the market risk of demand for the system.

To determine the value of the project in terms of the market risk of its cash flows, we use the relationship between expected return and risk (i.e., beta) from the Capital Asset Pricing Model (CAPM) (Huang and Litzenberger, 1988):

$$\rho_{X_1} = r_f + \beta_{X_1}(E(\tilde{r}_M) - r_f) \tag{8}$$

where r_f is the risk-free rate and $E(\tilde{r}_M)$ is the expected return on the market. Substituting (8) into (3), we have

$$PV(\tilde{X}_1) = \frac{(B - C)\bar{U} - F_1}{1 + r_f + \beta_{X_1}(E(\tilde{r}_M) - r_f)} \tag{9}$$

Substituting for β_{X_1} from (7) into (9), and solving for $PV(\tilde{X}_1)$ we have:

$$PV(\tilde{X}_1) = \frac{\{(B - C)\bar{U} - F_1\} - \lambda\text{Cov}((B - C)\tilde{U}, \tilde{r}_M)}{1 + r_f}. \tag{10}$$

where

$$\lambda \equiv \frac{E(\tilde{r}_M) - r_f}{\sigma^2(\tilde{r}_M)}.^4$$

Equation (10) can be written in a more compact form as

$$PV(\tilde{X}_1) = \frac{(B - C)(\bar{U} - \pi\beta_U) - F_1}{1 + r_f} \tag{11}$$

where $\pi \equiv [E(\tilde{r}_M) - r_f]$ is the "market risk premium." Since $[E(\tilde{r}_M) - r_f]$ must be positive (Huang and Litzenberger, 1988), $\partial(PV(\tilde{X}))/\partial\beta_U < 0$, so long as $B > C$. The value of a project varies inversely with the market risk of demand. Projects will be more valuable if the market risk of demand for the system is low or negative.

The market risk of demand can be estimated from a historical demand for the services provided by operations. Demand betas for the services provided by IT operations may be highly correlated with the beta coefficient on a firm's stock. Typical values for equity betas range from 0.36 for firms mining gold to 1.80 for firms in the air transport industry (Alexander and Sharpe, 1989). The corresponding CAPM expected returns for these two industries are 6.7% and 18.8%, respectively.[5] If demand betas for the outputs of IT investments are similar to equity betas, IT project betas could differ substantially from one firm to another and differences in β_U can have a large impact on the value of a project.

From (2) and (11), we can write the present value of the cash flow for alternative no. 2 as

$$PV(\tilde{X}_2) = \frac{(B-\gamma C)(\bar{U}-\pi\beta_U)-F_2}{1+r_f} = \frac{[B-C+(1-\gamma)C](\bar{U}-\pi\beta_U)-[F_1+(F_2-F_1)]}{1+r_f}. \quad (12)$$

Substituting (11) into (12) and simplifying, we have

$$PV(\tilde{X}_2) = PV(\tilde{X}_1) + \frac{[(1-\gamma)C](\bar{U}-\pi\beta_U)}{1+r_f} - \frac{(F_2-F_1)}{1+r_f} \quad (13)$$

The second term on the right hand side (RHS) is the expected present value reduction in variable costs and the third term on the RHS is the present value of the increase in periodic fixed costs. As seen from (13), choosing between outsourcing or in-house operations depends upon the reduction in variable costs and the increase in periodic fixed costs. This can be summarized as follows:

> As the market risk of demand decreases, the value of in-house operations increases, and vice-versa. That is, if a firm's demand for operations has a high covariance with the market, it is more likely that outsourcing will be preferred. If a firm's demand for operations is stable, i.e., it does not fluctuate with the market, it is more likely that in-house management of operations will be preferred.

Outsourcing is more attractive to firms whose demand for IT services is very sensitive to economic conditions, in that demand is high when the economy is booming and low when the economy is in a recession. Under these conditions, the firm will want to substitute the higher fixed cost under in-house operations for a higher variable cost under the outsourcing alternative. The intuition is that when the market demand beta is high, the variable component of costs is less of a burden, since it fluctuates with user demand. In contrast, the fixed component of costs is more of a burden since the ability to pay these costs fluctuates with user demand. Business activity at firms that manufacture big-ticket consumer products (e.g., automobiles, household appliances) is likely to be very sensitive to economic conditions. However, business activity at firms in the precious metals mining industry is less likely to be greatly affected by economic conditions. All else equal, therefore, firms in the automobile or household appliance business are more likely to find outsourcing operations beneficial than do firms in the precious metals mining industry.[6]

The two choices considered above are not equally risky. From (7), the market risks of these two alternatives are

$$\beta_1 = \frac{(B-C)}{PV(\tilde{X}_1)}\beta_U \quad \text{and} \quad \beta_2 = \frac{(B-\gamma C)}{PV(\tilde{X}_2)}\beta_U$$

Solving for β_U in the equation for β_1, and substituting that value into the equation for β_2, we have

$$\beta_2 = \frac{PV(\tilde{X}_1)}{PV(\tilde{X}_2)}\frac{(B-\gamma C)}{(B-C)}\beta_1 = \frac{PV(\tilde{X}_1)}{PV(\tilde{X}_1)+\Delta}\frac{(B-C)+(1-\gamma)C}{(B-C)}\beta_1 = \frac{PV(\tilde{X}_1)}{PV(\tilde{X}_1)+\Delta}\left[1+\frac{(1-\gamma)C}{(B-C)}\right]\beta_1 \quad (14)$$

where

$$\Delta = \frac{[(1-\gamma)C](\bar{U}-\pi\beta_U)}{1+r_f} - \frac{(F_2-F_1)}{1+r_f}.$$

If the expected present value decrease in variable costs equals the present value increase in fixed costs ($\Delta = 0$), i.e., the decision between in-house and outsourcing is value-neutral, then

$$\beta_2 = \left[1+\frac{(1-\gamma)C}{(B-C)}\right]\beta_1 > \beta_1, \quad \text{as long as } B > C.$$

This can be summarized as follows:

> In-house operations have a greater market risk than the outsourcing alternative. The reason is that, despite a lower variable cost, in-house operations have a larger fixed cost component that causes cash flows to be more sensitive to economic conditions. This also leads to a larger overall risk (variance) under the in-house alternative.

The latter can be seen from the variance of cash flows under the two alternatives:

$$\sigma^2_{X_1} = (B-C)^2\sigma^2_U < \sigma^2_{X_2} = (B-\gamma C)^2\sigma^2_U \quad \text{for } \gamma \in (0,1)$$

If the higher market risk is offset by larger benefits (B) and/or a net cost savings ($\Delta > 0$), in-house operations will be worthwhile.[7]

Other IT investment choices have similar characteristics. Managers are called upon to choose among different ways of providing a service or producing a new IT based product. For example, they are called upon to choose between in-house versus external support for end-users, or to determine whether software for a new system will be developed in-house or purchased from a software vendor. Such decisions often have similar cost and benefit structures to the in-house versus outsourcing scenario presented above.[8]

3.2. Interorganizational systems

Rapid decreases in communication costs, coupled with the possibility that interorganizational systems may provide a sustainable competitive advantage, have greatly increased interest in these systems (Johnson and Vitale, 1993; Lewis, 2001). As costs decrease with widespread business use of the Internet and firms learn to better manage the risks of interorganizational systems over the Internet, investments in interorganizational systems are likely to increase.

For many IT investments, benefits and variable costs are determined by use or demand for the system, as per our earlier assumptions. In some instances, however, benefits and variable costs may be separate, independent variables. In the case of interorganizational systems, managers often have to choose from alternatives where the benefits and costs are independent. Consider automated teller machine (ATM) investment decisions that many banks faced in the seventies and eighties.[9] The benefits of ATM investments included improvements in customer service (which presumably result in larger deposits and loans) and ATM transaction fees. The costs included those incurred to install ATM machines, adapt existing systems to accommodate ATM transactions, lease ATM sites, and operate ATMs (Banker and Kauffman, 1991; Dos Santos and Peffers, 1995; Kauffman and Lally, 1994).

Many of the risks associated with ATM benefits and costs are project-specific or are dependent on regional market conditions, e.g., the cost of adapting existing systems to accommodate ATM transactions and the effect of regional economic conditions on both benefits and costs. From a shareholder's perspective, these risks are irrelevant. Other risks, however, are dependent on general economic conditions and cannot be diversified away. For example, although ATMs may increase a bank's market share, the increase in revenues (from an increase in deposits and loans) will depend on economic conditions in the macro economy. Some of the costs associated with ATMs are also affected by economic conditions. For example, economic conditions affect the number of transactions at ATM sites, which in turn affect the cost of operating these sites.[10] Moreover, economic conditions can have different effects on ATM benefits and costs. High interest rates motivate customers to pay more attention to managing their demand deposits; customers are likely to make more frequent transfers between checking and savings accounts so as to have a larger proportion of their funds in savings accounts (which pay higher interest rates), thereby reducing bank revenues. At the same time, ATM variable costs may increase with an increase in interest rates, due to the increase in ATM transactions for which many banks do not directly charge customers.

We assume that the benefits per period provided by an interorganizational system, $\tilde{B}$, is stochastic with mean $\bar{B}$ and variance σ_B^2. For example, the new system may improve customer service and thereby enable the firm to increase market share. Benefits are assumed to be stochastic because the actual benefits will depend on a number of factors, including the realized market share and the price of the product. The variable cost of the system, $\tilde{C}$, also is stochastic with mean $\bar{C}$ and variance σ_C^2. As before, benefits and costs are incurred at the end of the period.

With these assumptions, the project's stochastic end-of period cash flow, $\tilde{X}$, is

$$\tilde{X} = \tilde{B} - \tilde{C} - F. \tag{15}$$

where F is the periodic fixed cost of operations. Substituting the expression for $\tilde{X}$ from (15) into (4), we have

$$\tilde{r}_X = \frac{(\tilde{B} - \tilde{C} - F)}{PV(\tilde{X})} - 1. \tag{16}$$

Substituting (16) into (6) and simplifying, the risk of the project is

$$\beta_X = \frac{1}{PV(\tilde{X})}\left[\frac{\mathrm{Cov}(\tilde{B}, r_M)}{\sigma^2(\tilde{r}_M)} - \frac{\mathrm{Cov}(\tilde{C}, r_M)}{\sigma^2(\tilde{r}_M)}\right].$$

The first and second terms in the square brackets are the market risk of benefits (β_B) and the market risk of costs (β_C), respectively. The market risk of costs is a measure of the co-variation of periodic costs with a composite market measure like the Wilshire 5000 index. Therefore,

$$\beta_X = \frac{1}{PV(\tilde{X})}[\beta_B - \beta_C]. \tag{17}$$

From (17), we see that if the variable cost of an IT project has a positive covariance with the market then their contribution to the project's overall market risk, β_X, will be negative. In other words, a project's market risk actually decreases as its market risk of costs increases. Alternatively, if variable costs have a negative covariance with the market, their contribution to project risk is positive and the project will have a higher overall market risk.

The value of the project in terms of the market risks of benefits and costs can be determined using the certainty equivalent form of the CAPM (Huang and Litzenberger, 1988):

$$PV(\tilde{X}) = \frac{\bar{X} - \lambda \operatorname{Cov}(\tilde{X}, \tilde{r}_M)}{(1 + r_f)}, \tag{18}$$

Substituting (15) into (18), we have

$$PV(\tilde{X}) = \frac{\bar{B} - \bar{C} - F - \lambda \operatorname{Cov}(\tilde{B} - \tilde{C}, \tilde{r}_M)}{(1 + r_f)}, \tag{19}$$

Now, substitute for λ in (19) to arrive at

$$\begin{aligned} PV(\tilde{X}) &= \frac{1}{1+r_f}\left[\{\bar{B} - \bar{C} - F\} - \frac{\{E(\tilde{r}_M) - r_f\}\operatorname{Cov}(\tilde{B} - \tilde{C}, \tilde{r}_M)}{\sigma^2(\tilde{r}_M)}\right], \\ &= \frac{1}{1+r_f}\left[\{\bar{B} - \bar{C} - F\} - \frac{\{E(\tilde{r}_M) - r_f\}\{\operatorname{Cov}(\tilde{B}, \tilde{r}_M) - \operatorname{Cov}(\tilde{C}, \tilde{r}_M)\}}{\sigma^2(\tilde{r}_M)}\right], \\ &= \frac{1}{1+r_f}\left[\{\bar{B} - \bar{C} - F\} - \pi(\beta_B - \beta_C)\right]. \end{aligned} \tag{20}$$

where $\pi = [E(\tilde{r}_m) - r_f]$. Since $\pi > 0$, it is clear from (20) that $\partial PV(\tilde{X})/\partial\beta_B < 0$ and $\partial PV(\tilde{X})/\partial\beta_C > 0$. This can be summarized as follows:

> Project value decreases as the market risk of benefits increases, and project value increases as the market risk of costs increases. All else equal, the larger the market risks of costs, the greater the value of the project. In other words, the value of an interorganizational system decreases as the market risk of the benefits of the system increases and value increases as the market risk of its costs increases.

This has interesting implications for the choices that firms face as they go about introducing systems that link the firm to its customers and suppliers. With many web-based initiatives, managers have a choice as to how they are compensated for the value delivered by these systems. They may choose to impose usage fees or fixed, periodic fees (e.g. monthly). They may also choose to bury their fees in the price charged for other products. The market risk of the benefits of these different alternatives will be different and affect the value of the system to the firm. Likewise, there often are a number of alternative ways of paying for such systems. When using an external vendor for these services, firms may have a choice between periodic fixed payments, fees based on use, or a combination of the two. If use has a high covariance with the market, market risk of costs will be high with use-based fees and will lead to an increase in project value. Thus, choices that affect the accrual of benefits and the incurrence of costs can have a substantial effect on system value.

3.3. *Optimal service levels*

Today, there are few activities in a firm that do not depend upon information technology. Many employees are left idle and a firm's interaction with its customers and suppliers are affected when computer systems fail to function as they should. As a result, there is an increasing need to provide a variety of services to users, including education, training, hardware maintenance and software support. An important aspect of this responsibility is that IT managers must determine the optimal level of service for different user services. For example, managers must determine the proper level of application software support for end-users.

The benefits and costs of IT services typically are a function of the service level. For example, benefits and costs are a function of the level of end-user support provided. Better end-user support may be achieved by staffing an information center (IC) with more knowledgeable consultants, but staffing with more knowledgeable consultants will increase periodic fixed costs. We assume that the cash flow from an investment in an IT service is described by

$$\tilde{X} = [B(s) - C]\,\tilde{U} - F(s) \tag{21}$$

where s is a choice variable that represents the "level of service." For service provided by "in-house" consultants, the level of service can be increased by increasing the number of staff or by employing higher quality staff. When service is outsourced, service contracts often specify in detail the level of service that is to be provided. For example, a contract may specify how quickly the service provider must respond to a service request. Equation (21) indicates that the benefits per use of the system are a function of the level of service that managers choose to provide. The periodic fixed costs also are a function of service level. This would be the case for in-house service where managers have to determine how they will staff a service center and/or what other IT resources they will make available through the service center. It also applies to outsourced service where a fixed periodic payment is made for a specific type and level of service, e.g., the response time to a service request.

We make the usual assumptions regarding benefits and costs: benefits are an increasing (concave) function of s and costs are an increasing (convex) function of s. Therefore, $B(s)$ and $F(s)$ satisfy the conditions: $B'(s) > 0,\ B''(s) < 0$ and $F'(s) > 0,\ F''(s) > 0$. The marginal benefits of service decrease as the service level increases, while the marginal cost of service increase as the service level increases.

We show here how demand risk affects the optimal service level. Given (21), if I_0 is the initial capital investment, the present value of the end-of-period cash flow, project NPV and project risk are:

$$PV(\tilde{X}) = \frac{(B(s) - C)(\bar{U} - \pi\beta_U) - F(s)}{1 + r_f},$$

$$NPV = PV(\tilde{X}) - I_0, \quad \text{and}$$

$$\beta_X = \frac{(B(s) - C)}{PV(\tilde{X})}\beta_U, \text{ respectively.}$$

The firm must choose s so as to maximize the net present value of the investment, i.e., $Max_s NPV$.

The necessary and sufficient first-order condition is

$$NPV' = \frac{B'(s)(\bar{U} - \pi\beta_U)}{1 + r_f} - \frac{F'(s)}{1 + r_f} = 0,$$

or

$$B'(s)(\bar{U} - \pi\beta_U) = F'(s). \tag{22}$$

Thus, the optimal service level is determined where the marginal expected benefits equal the marginal fixed cost.

From (22) we see that the optimal service level is implicitly a function of the market risk of demand. Using the implicit function theorem, we determine that

$$\frac{ds}{d\beta_U} = \frac{\pi B'(s)}{B''(s)(\bar{U} - \pi\beta_U) - F''(s)}, \tag{23}$$

which is unambiguously negative since $B''(s) < 0$ and $F''(s) > 0$.[11] Thus, s is inversely related to β_U. This can be summarized as follows:

> The higher the correlation of a firm's service usage rates with the state of the market/economy, the lower the optimal level of service that the firm should provide. The reason is that greater demand risk makes the investment in IT service less valuable, and therefore the firm is less willing to enhance service.

Service is less valuable to firms whose demand for IT services is very sensitive to economic conditions in that demand for service is high when the economy is booming and low when the economy is in a recession. This is because a higher service level results in a higher fixed periodic cost, while the benefits are determined by services consumed, which varies with the state of the economy.

This result also has interesting implications for multi-division firms, where the level of demand risk varies across business units as a result of differences in the activities, products and services, and IT applications deployed in different business units. For such firms, different service levels may be appropriate for a firm's business units. This complicates an IT manager's job, while at the same time providing opportunities to better manage IT services within the firm. Assuming all else is equal, this analysis suggests that better service should be provided to business units that have a lower demand risk. Because IT resources are scarce, services are often managed by assigning priorities to service requests. Firms should set priorities for service based upon the demand risk of the different business units, with higher priorities assigned to business units that have a lower demand risk.[12]

In the above scenario, we assumed that periodic fixed costs are a function of the service level. This will be the case if, for example, a firm has its own service department. If service is outsourced, variable costs often are a function of the service level (e.g., service charges are determined by service requests). For example, firms that outsource PC support may pay a periodic fixed amount for each PC and a charge for each request for service. We consider a model where benefits and variable costs are a function of the service level, and where both variables have a stochastic component. The cash flow from an investment in this type of IT service can be specified as

$$\tilde{X} = \tilde{B}(s) - \tilde{C}(s) - F$$

where

$$\tilde{B}(s) = g(s)\tilde{B} \quad g'(s) > 0,\ g''(s) < 0,\ \tilde{B} \overset{s}{=} N(\bar{B}, \sigma_B^2),$$

and

$$\tilde{C}(s) = q(s)\tilde{C} \quad q'(s) > 0,\ q''(s) > 0,\ \tilde{C} \overset{s}{=} N(\bar{C}, \sigma_C^2).$$

In this case, the present value of the cash flow, the net present value of the investment and the market risk of the investment are:

$$PV(\tilde{X}) = \frac{g(s)(\bar{B} - \pi\beta_B) - q(s)(\bar{C} - \pi\beta_C) - F}{1 + r_f},$$

$$NPV = PV(\tilde{X}) - I_0, \quad \text{and}$$

$$\beta_X = \frac{1}{PV(\tilde{X})}[g(s)\beta_B - q(s)\beta_C], \text{ respectively.}$$

The first-order condition for service optimization is

$$g'(s)(\bar{B} - \pi\beta_B) = q'(s)(\bar{C} - \pi\beta_C) \qquad (24)$$

As before, the first-order condition equates the marginal expected benefit with the marginal expected cost. However, now the optimal service level depends on both the market risk of benefits, β_B, and variable costs, β_C.

From (24) and using the implicit function theorem, the effects of β_B and β_C on the optimal level of service are

$$\frac{ds}{d\beta_B} = \frac{\pi g'(s)}{g''(s)(\bar{B} - \pi\beta_B) - q''(s)(\bar{C} - \pi\beta_C)} < 0,$$

and

$$\frac{ds}{d\beta_C} = \frac{-\pi q'(s)}{g''(s)(\bar{B} - \pi\beta_B) - q''(s)(\bar{C} - \pi\beta_C)} > 0,$$

respectively.

These results can be summarized as follows:

> The market risk of benefits has the same effect on the optimal service level as the market risk of demand in the previous model. However, an increase in the market risk of costs results in an increase in the optimal service level. The reason is that an increase in β_C will reduce the overall market risk of the project (β_X), which in turn increases the value of the project and therefore, the desired level of service.

If the service cost is dependent upon demand for service, firms whose demand for IT services is very sensitive to economic conditions should choose a higher level of service than firms whose demand is not sensitive to economic conditions. The intuition is that when the market demand beta is high, the variable component of costs is less of a burden, since it fluctuates with user demand. In contrast, a large fixed cost component is more of a burden since the ability to pay these costs fluctuates with user demand. If the variable costs of providing a service rises or falls in step with the market, a higher level of service should be provided. Service contracts with firms that specialize in providing services typically stipulate a service level that will be provided. For example, contracts will specify how quickly the service firm must respond to a service request. If services are paid for on a "service performed" basis, i.e., costs are variable, a higher level of service should be obtained if the market risk of costs is high.

4. Summary

Financial analysis of IT investments, although widely believed to be important, has received little attention in the literature. In this paper, we use financial analysis to gain insights into the relationship between different IT investment choices and the market risk and value of the investment. Our analysis shows how characteristics of three different IT investment decisions affect the market risk and value of the investment. The first type of decision compares outsourcing to in-house management of IT operations. We show that as the market risk of demand decreases, firms are less likely to outsource IT operations. Interorganizational systems often are set up such that the resulting costs and benefits have different market risks. In such cases, we show that the value of the project increases as the market risk of costs increase. More risky cost structures increase the value of the investment, because costs are higher when the firm can most afford to pay them and lower when firms can least afford to pay them. Finally, we consider decisions requiring managers to choose a service level. We show that the optimal service level is inversely related to demand risk. We also show that optimal service levels are directly related to the market risk of costs. Since the value of the investment is increasing in the market risk of costs, the firm is encouraged to enhance that value by providing a higher level of service.

This paper attempts to show how characteristics of the investment affect the market risk and value of some of the IT investment decisions that firms face today. Use of these models requires that the firm determine the market risk of demand, or the market risk of costs and benefits. These parameters often can be estimated from historical data captured by the firm. If appropriate historical data is not available, firms should determine whether the firm's historical stock market and accounting data (see, e.g., Mandelker and Rhee, 1984) may serve as good approximations of these parameters, or composite measures of them.

Our analysis raises interesting empirical questions pertaining to past IT investment decisions. Have managers been making sound decisions? For example, is IT outsourcing more prevalent among firms where demand for these services has a high covariance with the market? Are firms more likely to develop interorganizational systems when the periodic costs of the system have a high covariance with the market? Do multi-divisional firms provide better service to divisions where the demand risk is lower? These are questions that can be answered by empirical studies. Such answers can address a long-standing debate as to whether firms have been making sound IT investment decisions.

This paper can help practitioners understand why other firms, whether they are in the same industry or a different industry, may make very different IT investment decisions, even though it may seem that they face identical conditions. Practitioners should realize that the choices they make that affect the cost and benefit structures of the project could have a substantial effect on the value of a project. Finally, in an age where "service" is becoming critically important, this type of analysis can be used to develop better service policies and procedures.

Our analysis is fairly general. Finer calibration of the costs and benefits of IT investments may be achieved by specifying models that are specific to a particular investment situation. For example, if the primary benefit of an order processing system is to reduce inventory levels, one might include in the cash flow specification a functional relation between inventory reduction and investment benefit from inventory theory. More detailed specifications of benefits and costs may provide additional insights into the relationship between IT investment risks and value.

Appendix: Service Contracts with Different Benefits and Fixed Costs

IT managers are called upon to choose between alternatives with different benefits and fixed costs. For example, a firm may have to choose between software maintenance contracts with one of two firms. The first is a local firm that can respond to maintenance requests quickly and can be on site within a few hours. The second is a firm in India that will perform many of the software maintenance activities remotely and, when necessary, will send personnel to the site.[13] In the latter case, response time will obviously be longer. Both firms require a fixed periodic charge, in addition to a variable cost. The fixed charge for the local firm, however, is much higher. For simplicity, we assume that the variable costs are the same. In this case, the cash flows for the two alternatives may be described by

$$\tilde{X}_1 = (B - C)\tilde{U} - F_1$$

and

$$\tilde{X}_2 = (\rho B - C)\tilde{U} - F_2, \quad 1 < \rho < \infty \quad \text{and} \quad F_2 > F_1$$

where $\tilde{X}_2$ is the cash flow for a contract with the local firm. For the local contract, benefits are larger, but so is the periodic fixed cost. The present values of cash flows for the two contracts are

$$PV(\tilde{X}_1) = \frac{(B - C)(\bar{U} - \pi\beta_U) - F_1}{1 + r_f}$$

and

$$\begin{aligned} PV(\tilde{X}_2) &= \frac{(\rho B - C)(\bar{U} - \pi\beta_U) - F_2}{1 + r_f} \\ &= \frac{[(B - C) + B(\rho - 1)](\bar{U} - \pi\beta_U) - [F_1 + (F_2 - F_1)]}{1 + r_f} \end{aligned}$$

Writing $PV(\tilde{X}_2)$ in terms of $PV(\tilde{X}_1)$, we have

$$PV(\tilde{X}_2) = PV(\tilde{X}_1) + \frac{B(\rho - 1)(\bar{U} - \pi\beta_U)}{1 + r_f} - \frac{(F_2 - F_1)}{1 + r_f}$$

The second term on the right-hand-side is the expected present value of the additional benefits for a contract with the local firm, whereas the third term is the present value of the additional fixed costs for a contract with the local firm. As the market risk of demand for software maintenance *increases*, the value of a contract with the local firm *decreases* and vice-versa. That is, if demand for software maintenance has a high covariance with the market, it is less likely that a contract with the local firm will be preferred.

The market risks of the two alternatives are

$$\beta_1 = \frac{(B - C)}{PV(\tilde{X}_1)}\beta_U \quad \text{and}$$

$$\beta_2 = \frac{(\rho B - C)}{PV(\tilde{X}_2)}\beta_U, \text{ respectively.}$$

Solving for β_U from the equation for β_1 and substituting that value into the equation for β_2, we have

$$\begin{aligned}\beta_2 &= \frac{PV(\tilde{X}_1)}{PV(\tilde{X}_2)}\frac{(\rho B - C)}{(B - C)}\beta_1 \\ &= \frac{PV(\tilde{X}_1)}{PV(\tilde{X}_1) + \Psi}\frac{[(B - C) + B(\rho - 1)]}{(B - C)}\beta_1 \\ &= \frac{PV(\tilde{X}_1)}{PV(\tilde{X}_1) + \Psi}\left[1 + \frac{B(\rho - 1)}{(B - C)}\right]\beta_1\end{aligned}$$

where

$$\Psi \equiv \frac{B(\rho - 1)(\bar{U} - \pi\beta_U)}{1 + r_f} - \frac{(F_2 - F_1)}{1 + r_f}$$

If the expected present value of the additional benefits is equal to the present value of the difference in the fixed costs (i.e., $\Psi = 0$), we have

$$\beta_2 = \left[1 + \frac{B(\rho - 1)}{(B - C)}\right]\beta_1 > \beta_1, \text{ as long as } B > C.$$

Thus, the additional fixed cost associated with the contract with the local firm increases the market risk of that alternative relative to the contract with the Indian firm.

Notes

1. Strictly speaking, we also assume that shareholders of firms hold diversified portfolios and are only concerned with market risk, i.e., the risk that remains in a well-diversified portfolio.
2. The assumption that the benefits for the two alternatives are the same ignores strategic interactions. For example, an in-house program may provide more reliable service and may reduce the costs of monitoring. This could lead to differential benefits. In the appendix, we consider the case where benefits and costs are different.
3. The basic CAPM assumptions are presumed to hold for the analysis in this paper.
4. This is the certainty equivalent form of project value. Although it gives the same project value as the risk-adjusted discount rate formulation in (9), it differs in how project value is adjusted for market risk. In (10), risk is adjusted in the numerator and then discounted at the risk-free rate of interest. Thus, λ can be interpreted as the "market price of risk" and $Cov((B - C)U, r_M)$ as the quantity of risk.
5. The expected returns are estimated using an historical average risk-free rate of 3.7% and a market risk premium of 8.4% (Ibbotson Associates, 1991).
6. In some instances, the benefits of outsourcing versus in-house service may be unequal. Considering a case where the benefits are different is straightforward. For such a case, we can determine how much of difference in benefits there has to be for outsourcing to be preferred to in-house service, or vice-versa.
7. We have assumed that benefits are independent of fixed costs. Benefits could be a function of fixed costs. In the Appendix we show how different benefits and fixed costs affect market risk and project value.
8. Typically, a customized system will have a larger front-end cost that a software package purchased off the shelf. However, the (variable) costs associated with changes to the original system that are inevitably required over a system's life, are likely to be lower when the system is developed in-house.
9. We use the ATM example because its effects have been widely studied and we now have a reasonably good idea of the costs and benefits.
10. Breakdowns increase with use and machines have to be visited more frequently to collect deposits and replenish cash as use increases.
11. We assume that $\bar{U} > \pi\beta_U$. If this were not the case, then the project would never have a positive NPV.
12. It should be notes that we are assuming that the benefits of the services are the same across all business units, which may or may not be the case.
13. General Electric's Appliance division was faced with this choice some years ago.

References

Alexander GJ, Sharpe WF. *Fundamentals of Investments*. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1989.

Banker RD, Kauffman RJ. Case study of electronic banking at Meridian Bancorp. *Information and Software Technology* 1991;33(3): 200–2004.

Benaroch M, Kauffman RJ. A case for using real options pricing analysis to evaluate information technology project investment. *Information Systems Research* 1999;10(1):70–86.

Benaroch M, Kauffman RJ. Justifying electronic banking network expansion using real options analysis. *MIS Quarterly* 2000;24(2): 197–225.

Brynjolfsson E. Technology's true payoff. *InformationWeek* 1994; 496(October 10):34–36.

Brynjolfsson E, Hitt L. Paradox lost? Firm-level evidence on the returns to information systems spending. *Management Science* 1996;42(4):541–558.

Campbell JA. Real options analysis of the timing of IT investment decisions. *Information and Management* 2002;39:337–344.

Chaudhury A, Nam K, Rao HR. Management of outsourcing: A bidding perspective. *Journal of Management Information Systems* 1995;12(2):131–159.

DeLone WH, McLean ER. Information systems success: In search of the independent variable. *Information Systems Research* 1992;3(1):60–95.

Dos Santos BL. Justifying investments in new information technologies. *Journal of Management Information Systems* 1991;7(4):71–89.

Dos Santos BL, Peffers K. Rewards to investors in innovative information technology applications: First movers and early followers in ATMs. *Organization Science* 1995;6(3):241–259.

Dos Santos BL, Peffers K, Mauer DC. The impact of information technology investment announcements on the market value of the firm. *Information Systems Research* 1993;4(1):1–23.

Huang C, Litzenberger RH. *Foundations for Financial Economics*. New York, NY: Elsevier Science Publishing Co., Inc., 1988.

Johnson HR, Vitale MR. Creating competitive advantage with interorganizational systems. *MIS Quarterly* 1993;12(2):152–165.

Kambil A, Henderson J, Mohsenzadeh H. Strategic management of information technology investments: An options perspective. In: Banker RD, Kauffman RJ, Mahmood MA, eds. *Strategic Information Technology Management: Perspectives on Organizational Growth and Competitive Advantage*. Harrisburg, PA: Idea Group Publishing, 1993:163–178.

Kauffman RJ, Kriebel CH. Measuring and modeling the business value of IT. In: Strassman PA, Berger P, Swanson EB, Kriebel CH, Kauffman RJ, eds. *Measuring Business Value of Information Technologies*. ICIS Press, 1988:93–120.

Kauffman RJ, Lally L. Value platform analysis perspective on customer access information technology. *Decision Sciences* 1994;25(5/6):767–794.

Keen PGW. Value analysis: Justifying decision support systems. *MIS Quarterly* 1981;5(1):1–15.

King JL, Schrems EL. Cost-benefit analysis in information systems development and operation. *Computing Surveys* 1978;10(1):19–34.

Lacity MC, Hirschheim R. *Information Systems Outsourcing: Myths, Metaphors and Reality*. New York: Wiley, 1993.

Lee J, Kim Y. Effect of partnership quality on IS outsourcing: Conceptual framework and empirical validation. *Journal of Management Information Systems* 1999;15(4):29–61.

Lewis I. Logistics and electronic commerce: An interorganizational systems perspective. *Transportation Journal* 2001;40(4):5–13.

Loh L, Venkatraman N. Diffusion of information technology outsourcing: Influence sources and the kodak effect. *Information Systems Research* 1992;3(4):334–358.

Malone TW, Yates J, Benjamin RI. Electronic markets and electronic hierarchies. *Communications of the ACM* 1987;30(6):484–497.

Mandelker GN, Rhee SG. The impact of the degrees of operating and financial leverage on systematic risk of common stock. *Journal of Financial and Quantitative Analysis* 1984;18(1):45–57.

Mukhopadhyay T, Barua A, Kriebel CH. Information technologies and business value—an analytic and empirical-investigation. *Information Systems Research* 1995;6(2):U2–U2.

Nam K, Rajagopalan S, Rao HR, Chaudhury A. A two-level investigation of information systems outsourcing. *Communications of the ACM* 1996;39(7):36–44.

Strassman PA. Management productivity as an IT measure. In: Strassman PA, Berger P, Swanson EB, Kriebel CH, Kauffman RJ, eds. *Measuring Business Value of Information Technologies*. ICIT Press, 1988.

Brian Dos Santos holds the Frazier Family Chair in Computer Information Systems in the College of Business & Public Administration at the University of Louisville. He has been on graduate business school faculties at Purdue University, University of Wisconsin at Madison and Case Western Reserve University. His primary research interests are in the areas of information technology investment justification, electronic commerce and technology-assisted education. He has published widely in these areas. He has been engaged in a consulting capacity by a number of large firms, including UPS, Motorola, Ameritech, Northern Telecom and Dow Elanco.