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Information Technology Portfolio Management:

Literature Review, Framework, and Research Issues

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ABSTRACT

There is significant interest in managing IT resources as a portfolio of assets. The concept of IT portfolio management (ITPM) is relatively new, compared to portfolio management in the context of finance, new product development (NPD), and research and development (R&D). This article compares ITPM with other types of portfolio management, and develops an improved understanding of IT assets and their characteristics. It presents a process-oriented framework for identifying critical ITPM decision stages. The proposed framework can be used by managers as well as researchers.

Keywords: *business value of IT; IT portfolio management*

INTRODUCTION

IT investments constitute a major portion of organizations' capital budgets in many organizations (Jeffery & Leliveld, 2004). However, some authors question the business value of IT (Carr, 2003), and the actual contribution of IT to organizational performance is the subject of debate (Kohli & Devaraj, 2003). IT managers are constantly under pressure to justify their IT investments and demonstrate the business value of IT. For most companies, selecting a project that would fit the corporate strategy—and therefore maximize the business value—is a challenging process (Jeffery & Leliveld, 2004). In addition, the high failure rate of IT projects in many organizations is a cause for concern. A study by Standish Group showed that only 28% of IT projects succeed in 2004, compared to 34% a year earlier (Hayes, 2004).

Hence, there has been significant interest in effective management of information technology investments (Cimral & Lawler, 2002; Datz, 2003; Jeffery & Leliveld, 2004; Reyck, Grushka-Cockayne, Lockett, Calderini, Moura,

& Sloper, 2005). Organizations recognize that they have portfolios of IT assets. Each component of the portfolio (e.g., applications, projects, and infrastructure) serves a different purpose and needs to be managed differently, while recognizing the interdependencies between these components. Several organizations have undertaken IT portfolio management (ITPM) projects (Datz, 2003; Jeffery & Leliveld, 2004; Weill & Vitale, 1999). An increasing number of vendors and consultants offering ITPM products , services, and books are beginning to appear (Fitzpatrick, 2005; Maizlish & Handler, 2005). However, organizations have different maturity levels when it comes to implementing ITPM (Jeffery & Leliveld, 2004). There are significant additional benefits that can be obtained from better understanding and implementation of ITPM (Weill & Aral, 2006).

From a research perspective, there are several studies that address portfolio management. These research studies span diverse fields, such as new product development (NPD) (Cooper, Edgett, & Kleinschmidt, 1997, 1999), research and development (R&D) (Dickinson, Thornton, & Graves, 2001), financial portfolio management (FPM) (Reilly & Brown, 2002), and IT (Jeffery & Leliveld, 2004). However, an analysis of similarities and differences between ITPM and other types of portfolio management is lacking in the literature. Such an analysis would help researchers, as well as managers, apply ideas from other types of portfolio management that can be used for ITPM.

From an MIS perspective, there are very few studies directly related to ITPM (Jeffery & Leliveld, 2004; Weill & Aral, 2006; Weill & Vitale, 1999). ITPM as a concept remains underdeveloped. However, there are several streams of research that seem to be relevant to ITPM. These include business values of IT (Devaraj & Kohli, 2003), IT project management (Wallace & Keil, 2004; Wallace, Keil, & Rai, 2004), IT adoption and use (Jasperson, Carter, & Zmud, 2005; Venkatesh, Morris, Davis, & Davis, 2003), IT success (DeLone & McLean, 2003), strategic use of IT (Bhatt & Grover, 2005; Piccoli & Ives, 2005), strategic IS planning (Grover & Segars, 2005), business process change (Kettinger & Grover, 1995), and others. Hence, there is a need to better understand how these streams of research are related to ITPM, and further develop ITPM from a research perspective.

This article views an organization's IT portfolio as comprising a set of assets: IT infrastructure assets (the hardware and software that support IT applications such as servers, workstations, database software, and network infrastructure), application assets, project assets, and IT-related human resource assets. This view of the IT portfolio mirrors the way many organizations manage their IT assets, and is discussed in Section 3. Application, infrastructure, and project components of the IT portfolio are the focus of this article, since managing the human component of the IT portfolio is an important topic in its own right.

Jeffrey and Leliveld (2004, p. 41) define ITPM as "managing IT as a portfolio of assets, similar to a financial portfolio, and striving to improve the performance of a portfolio by balancing risk and return." This article views ITPM as *a continuous process to manage IT project, application, and infrastructure assets and their interdependencies, in order to maximize portfolio benefits, minimize risk and cost, and ensure alignment with organizational strategy over the long run.* This view of ITPM specifically recognizes different types of IT assets, the continuous process nature of ITPM, and identifies major dimensions (alignment, benefits, costs, risks, and interdependencies) that need to be considered in managing IT as a portfolio of assets. It is important to note that some researchers would consider alignment to be a type of benefit. However, identifying it as a separate characteristic of an IT portfolio helps to maintain focus on the important goal of aligning IT with organizational strategy.

This article focuses on the following questions:

i. What are the core concepts of (other types of) portfolio management?

ii. How do these core concepts apply to IT portfolio management?
iii. How do relevant, major, existing MIS research streams relate to ITPM?
iv. How do existing IT management practices relate to ITPM?

This article presents a cumulative body of relevant knowledge to aid future development of ITPM by addressing the above questions. It develops a conceptual framework for better understanding and managing ITPM by (a) reviewing and synthesizing related literature, (b) identifying core concepts of portfolio management that cut across financial, NPD, and R&D contexts (e.g., assets, alignment, costs, benefits, risks, interdependencies), and (c) developing these core concepts in an MIS context by integrating relevant ideas from MIS literature with ideas from other types of portfolio management. The proposed framework systematically identifies major steps and decisions in ITPM. It could be of use to researchers who are interested in further development of ITPM, as well as practitioners. Areas for future research are identified by using this framework to compare existing research in MIS with research in other types of portfolio management. The use of this framework in an organizational context is illustrated using an example.

The article is organized as follows: Section 2 provides a review of related literature from the fields of NPD, R&D, financial portfolio management, and MIS. Core concepts of portfolio management in the context of IT are discussed in Section 3. A framework for understanding ITPM decisions and processes is described in Section 4. An example to illustrate the use of the ITPM decisions and processes framework is provided in Section 5. Managerial Issues are discussed in Section 6. Conclusions are presented in Section 7.

LITERATURE REVIEW

Portfolio management is typically associated with financial assets. Besides finance, other fields such as NPD, R&D, and MIS have used portfolio management concepts. This section summarizes relevant research.

Financial Portfolio Management

Portfolio management in finance (Reilly & Brown, 2002) deals with managing a variety of asset classes (such as stocks, bonds, cash) in order to maximize return for some specified period of time, while attempting to minimize risk. Each asset class can contain a variety of subclasses. These include different types of stocks (small-cap, mid-cap, international, and so on) and different types of bonds (domestic, international, junk, short-term, long-term, inflation adjusted, and so on). These asset classes vary in terms of their risk-return characteristics, as well as liquidity. Risk-return characteristics of portfolios are different from those of individual stocks, and are influenced by the degree of correlation between assets in the portfolio.

Financial asset holders typically select a portfolio of assets in relation to their strategic goals (e.g., retirement) and risk tolerance. They periodically trade (buy and sell) assets in order to rebalance (ensure that their portfolio continues to be aligned with their strategic goals). Trading costs influence the frequency with which they trade. Relatively liquid assets can be traded at relatively lower trading costs. The value of each financial asset is typically determined by markets. Costs of these assets include actual asset costs, trading fees, and asset management fees (for managing or maintaining a portfolio). Effective management of a financial portfolio comprising different types of assets often results in higher expected returns with an acceptable level of risk over a defined time horizon.

Major research issues in financial portfolio management include portfolio selection, risk-return characteristics of different types of financial assets, portfolio management, the impact of trading costs, and a variety of other issues (Elton, Gruber, Brown, & Goetzmann, 2002).

NPD Portfolio Management

NPD portfolio components are projects which result in products that can be marketed. The literature suggests numerous reasons for the popularity of NPD portfolio management practices (Cooper & Edget, 2003). These include scarcity of organizational resources, project failure rate, and the misalignment between projects and strategic decisions. Many companies find portfolio management useful in providing them with systematic ways to decide which projects to undertake and to help them track the deployment of existing resources (Cooper & Edget, 2003; Cooper et al., 1999). Cooper, Edgett, and Kleinschmidt (2004a, 2004b, 2004c) examined best portfolio management practices in several organizations, and found that portfolio management approaches are related to higher organizational NPD performance. More specifically, research shows that high-performing companies (in terms of revenue percentage from new products or other metrics) have a higher proportion of innovative projects in their portfolio than low-performing companies. This emphasizes the importance of the mix of projects in a portfolio. The NPD literature contains several streams of research on portfolio management.

One stream extends financial portfolio management and microeconomic theory to incorporate the unique characteristics of new product investments. Leong and Lim (1991) developed a multiperiod portfolio evaluation framework based on financial portfolio concepts. Relevant financial concepts include the correlation between projects (divisions), interproject relations (synergies), changes in risk and returns over time, and the effect of buy/sell decisions on portfolio performance. Devinney and Stewart (1988) extended the microeconomic theory of the firm, while paying close attention to "interdependency between demand and supply in new product line investment." The model presented in their article takes into consideration the interaction between cost, revenue, and profitability of products.

Another stream of research presents different project selection methodologies a firm can use to maximize its return and achieve the right balance of projects. In a series of articles, Cooper et al. (1997, 1999) evaluate different project selection and value maximizing practices employed by a set of firms. Examples of these practices are: NPV, productivity index, and scoring models. Cooper et al. (1999) recommended the use of hybrid portfolio evaluation methods. Financial methods such as NPV, IRR, or productivity index, strategic methods, scoring models, and finally, bubble diagrams where projects can be viewed in terms of risk and reward can be used to evaluate projects (Cooper et al., 1999). Other combinations of methods can be used when evaluating and selecting new projects. For example, managers can use a mix of analytic hierarchy process (AHP) and simulations to help them decide on the best project, based on predefined criteria (Ayag, 2005). Loch and Kavadias (2002) developed a dynamic model of selecting new product lines using a marginal analysis approach. The dynamic model takes into consideration multiple factors, such as interaction of multiple product lines (substitution or complementary), resource synergies, uncertainties, potential size of the market segment, and management risk aversion.

R&D Portfolio Management

The use of portfolio management in R&D resource allocation began in the 1980s (Dickinson et al., 2001). Because high-technology firms cannot afford to develop one product at a time, they face the challenge of concurrently managing multiple R&D projects using shared resources (Verma & Sinha, 2002). The goal of R&D portfolio management is to optimize the resource allocation among projects in a way that balances risk, benefits, and align projects with corporate strategies (Dickinson et al., 2001). Components in a R&D portfolio are projects. Project selection and evaluation represent a major managerial effort in R&D portfolio management. Researchers have identified different types of interdependencies among R&D projects, such as resource interdependencies, outcome interdependencies, and benefit interdependencies (Chien, 2002; Verma & Sinha, 2002). Because of the existence of the various interdependencies, the combination of individually optimal projects does not necessarily constitute the optimal portfolio (Chien, 2002). Therefore, portfolio management techniques which take into consideration all possible projects at the same time are required.

There are a wide range of R&D portfolio management techniques with varying metrics and evaluation/selection methods. The metrics used to evaluate and select a project include quantitative (e.g., ROI) and qualitative (e.g., alignment with company strategy) measures. Different portfolio management techniques have been developed to evaluate different metrics. Mathematical and scoring/weighing models could be used when quantitative measures are available (Dickinson et al., 2001; Ringuest et al., 2000; Stummer et al., 2003). Matrix and charting could be used to explore qualitative measures (MacMillan & McGrath, 2002; Mikkola, 2001). Professional judgment is often considered another valuable decision source in R&D portfolio management (Dickinson et al., 2001).

Portfolio Management in IT

The information systems literature contains few studies on portfolio management. Similar to research in other disciplines, researchers have examined methods and models to measure the risk and value of different portfolio components, such as project portfolio risk (McFarlan, 1981) and application health (Weill & Vitale, 1999). Others have presented models to select projects in an IT portfolio (Bardhan & Sougstad, 2004). Although several methods to measure the value and risk of IT portfolio components exist, many companies are missing the full benefits of ITPM. According to a survey of 1,000 CIOs—while 89% of them were aware of ITPM, and 65% believed that it yields significant business value—only 17% think they have realized ITPM's full value (Jeffery & Leliveld, 2004). Hence, companies could benefit from an improved understanding of ITPM. ITPM is not a new topic in information systems research; it goes back to the early 1970s, when researchers started studying information systems within the context of the entire organization (Lucas, 1973). Recently, there has been a renewed interest in the topic, given the challenges facing companies in managing their IT assets more effectively. This renewed interest is due, in part, to articles such as Carr (2003) that have questioned the business value of IT.

Jeffrey and Leliveld (2004) discussed best practices in ITPM based on a survey and interviews. They also suggest that an IT portfolio maturity model be used to characterize different levels of ITPM implementation in organizations. Weill and Broadbent (1998) classified IT assets into transactional assets, informational assets, strategic assets, and infrastructure assets. They illustrate that the relative proportion of these four types of assets in an organization is related to corporate strategy. For example, an organization whose business strategy is based on cost leadership would emphasize transactional assets, while an organization whose business strategy is based on agility would emphasize strategic assets. Weill and Aral (2006) emphasized that the effective implementation of ITPM in organizations is related to developing IT savvy, which is a set of five interrelated characteristics. Of these five characteristics, three (use of IT for internal and external communication, internet use, and digital transactions) are practices related to IT use, and two (companywide IT skills, and management involvement) are competencies.

UNDERSTANDING ITPM

Financial, NPD, R&D and IT Portfolios: Similarities and Differences

Financial, NPD, R&D, and IT portfolio management have similarities and differences. This section analyzes these similarities and differences using the following characteristics or dimensions of portfolios: portfolio components, strategic alignment, benefits, costs, risks, and interdependencies. An analysis of each dimension includes a discussion of MIS research related to that dimension. This analysis forms the basis for the ITPM decision framework presented in the following section.

Portfolio Components or Assets

Asset types in the case of FPM include different types of stocks and bonds. Portfolio assets are typically projects in the case of NPD and R&D portfolios. However, there could be different types of projects, just as there are different types of stocks or bonds.

Asset classes in IT portfolios include projects, applications, and infrastructure.[1] Figure 1 illustrates the interrelationship between these three asset classes. Completed IT projects could result in applications (e.g., purchasing systems), or infrastructure components (e.g., messaging system). Infrastructure components, in turn, support applications.

Of these, IT projects have been extensively researched, particularly from project success and risk management perspectives (Schmidt, Lyytinen, Keil, & Cule, 2001; Wallace & Keil, 2004; Wallace et al., 2004) and continue to be an active area of research. MIS research on IT applications spans several streams. These include IT adoption and use (Venkatesh et al., 2003), IT success (DeLone & McLean, 2003), and deriving business value from applications (Devraj & Kohli, 2003). Research on IT infrastructure is relatively new and includes streams, such as infrastructure value (Kumar, 2004), infrastructure flexibility (Byrd & Turner, 2000; Duncan, 1995), and infrastructure management (Weill & Broadbent, 1998; Weill & Vitale, 2002).

A benefit of viewing IT assets as projects, applications, and infrastructure is that it mirrors the way IT assets are managed in organizations. In the case of financial portfolios, groups of specialists manage different types of assets. For example, fixed income (bond) securities are managed by different groups of managers than equities or stocks. Similarly, in the case of IT portfolios, projects are typically managed by project and application development groups, applications are managed by support groups and infrastructure is managed by architects and network or infrastructure support groups. While there is some job rotation between these groups, the organization structure in many IT organizations distinguishes between project or development groups, application support groups, and infrastructure support groups. Different (sometimes overlapping) skills are required for project management, application development, application support, and infrastructure support. Table 1 summarizes some key characteristics of IT assets. These characteristics are discussed in the following sections.

IT portfolios include architecture, project, and infrastructure subportfolios (Figure 2). Researchers studying project subportfolios have examined issues such as interdependent project

Figure 1. Relationship among projects, infrastructure, and applications

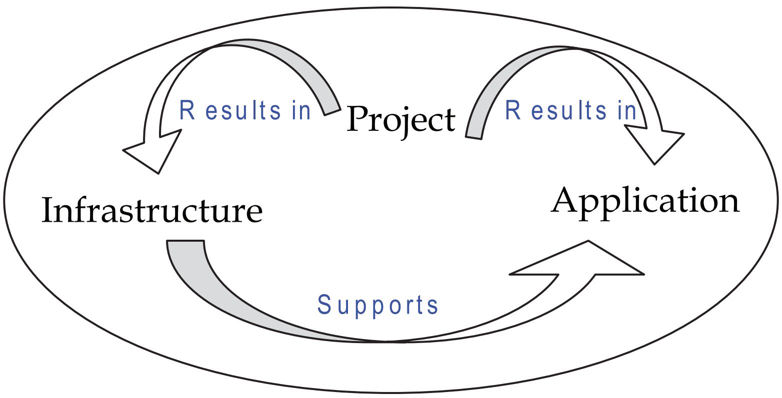


Table 1. Key characteristics of projects, applications, and infrastructure assets

Characteristic	Projects	Applications	Infrastructure
Management responsibility	Project managers	Support groups	Architecture groups
Benefits	Determined as part of a business case.	Determined after implementation	Determined after implementation. Relatively difficult to determine
Costs (major)	Programming costs +purchased hardware/software costs + project management costs	Application license costs + support (labor) costs+ allocated infrastructure costs	License costs+ support (labor) costs
Risks (major)	Risks of the project not being completed on time, within budget, or not producing desired benefits	Risks of application downtime and risk of the application not being adopted or used as planned	Risks of infrastructure downtime
Alignment with Strategy	Projects are related to strategic goals (e.g. reduce cost)	Applications support strategic business processes	Strategic architecture decisions impact organizational performance

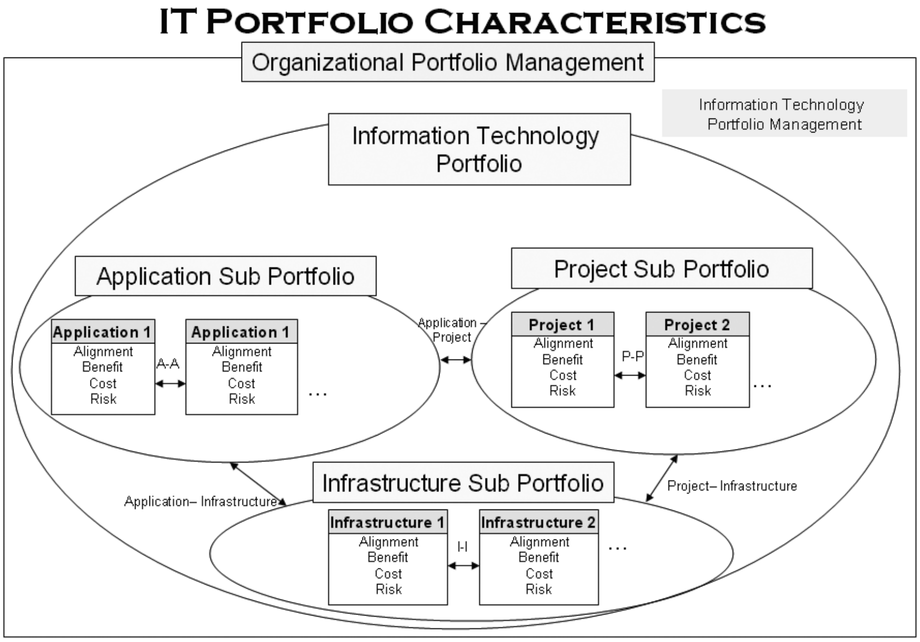
evaluation (Bardhan & Sougstad, 2004) and use of different project management approaches depending on the type of project (Applegate, Austin, & McFarlan, 2006). Reyck et al. (2005) classified implementations of IT project portfolio management (PPM) into three stages and provide empirical evidence (based on European data) that adoption of PPM is highly correlated with improved project performance. Weill and Vitale (1999) proposed a framework for analyzing an organization's application subportfolio based on benefits and risk, and managing applications based on this analysis.

Characteristics of IT Portfolio Components

Strategic Alignment

All four types of portfolio management (FPM, NPD, R&D, ITPM) emphasize the need to align the portfolio with long-term goals or organizational strategies. However, there are some differences. NPD and R&D typically focus on a few products or processes. However, IT is significantly more pervasive than NPD and R&D, because IT investments can impact a variety of processes or products. Some of the tools that have been proposed to align NPD and R&D projects with corporate strategy, such as scoring models, can also be used to align IT investments with corporate strategy. However, strategic planning for IT is likely to be more complex, and involves a variety of diverse stakeholders. MIS research (Grover & Segars, 2005; Newkirk & Lederer, 2006) which emphasizes the importance of a strategic information systems planning (SISP). This stream of research has identified important process elements of SISP (Newkirk & Lederer, 2006) and the results of successful SISP (Grover & Segars, 2005; Segars & Grover, 1998). SISP success measures include increased alignment, improved analysis and understanding of an organization's relationship with IT, improved

Figure 2. Information technology portfolio characteristics: components, alignment, benefit, cost, risk, and interdependency



cooperation, and important capabilities such as the ability to identify key problem areas and flexibility to adapt to unanticipated changes. Research on financial portfolios, NPD, R&D, and IT portfolios has recognized the need to have a mix of different types of assets in the portfolios. The mix of different types of assets would be related to an organization's strategic goals. As discussed earlier, Weill and Broadbent (1998) classify an organization's IT investments into transactional, informational, and strategic, and illustrate that the relative proportions of these types of assets is related to an organization's strategy. Weill and Aral (2006) provide empirical evidence of organizational benefits from planned portfolios that include strategic investments in IT.

Benefits

Organizations would typically like measurable financial benefits that could be quantified by means of financial calculations from all investments. Financial assets often have market-determined values. Hence, determining the value of a portfolio is relatively easy. However, the value of a portfolio could vary considerably over time. The value of NPD and R&D portfolios is typically based on projected project benefits. NPD project benefits are typically based on market research and projected sales. R&D project benefits could be more difficult to estimate, compared to NPD project benefits, depending on the type of R&D project, since R&D projects often require follow-up commercialization projects. Scoring models or financial measures are typically used to determine value, though several more sophisticated methods, often based on financial management, have been proposed, as have hybrid approaches.

There is an extensive body of literature on the business value of IT (Devaraj & Kohli, 2003). Several methods for evaluating the business value of IT projects have been proposed. These include traditional financial measures

(Ross & Beath, 2002) and more sophisticated methods, based on financial asset evaluation (Benaroch & Kauffman, 1999; Santos, 1991). However, it is well-recognized that it is often difficult to quantify the benefits of IT projects, particularly if they relate to infrastructure (Kumar, 2004). It has also been recognized that different types of evaluation methods may be appropriate, depending on the type of IT project (Ross & Beath, 2002). Hence, quantifying the benefits of a portfolio of IT projects can be difficult.

A growing body of literature exists on post hoc analysis of the business value of IT applications (Kohli & Devaraj, 2003). These studies typically use econometric analyses to determine the value of IT applications. The MIS literature recognizes that the business value of IT investments is influenced to a large extent by complementary investments in training and business processes (Weill & Aral, 2006), and by the extent to which an application is used in the organization (Devaraj & Kohli, 2003).

The business value of IT infrastructure investments can be particularly difficult to determine. Their value is determined in part by the value of applications they support, and in part by their ability to enhance organizational flexibility. Hence, relatively sophisticated techniques, such as those described in Kumar (2004), may be required.

In the case of financial portfolio management, it is possible to assign a value to a portfolio of assets. The total value of NPD and R&D portfolios can be estimated if projected financial metrics are available for projects. However, the total value (benefit) of an IT portfolio (comprised of projects, applications, and infrastructure) can be difficult to articulate, since different methods of determining the values of these portfolio components may be used at the portfolio component or subportfolio level, and determination of value is imprecise. Scoring models and approximate financial valuation using appropriate approximate techniques for projects, infrastructure, and applications is possible. Additional research on approaches to specifying portfolio value is required.

Costs

Costs of financial assets can be classified into acquisition costs, holding costs, and disposal costs. Acquisition costs include the purchase price and trading commissions. Holding costs typically include different types of asset management fees, which could vary depending on the type of asset (e.g., savings accounts, brokerage accounts). Disposal costs typically refer to commissions. In the case of NPD and R&D portfolios, organizations are concerned primarily with project costs. Completed projects result in products or services, which are then commercialized.

In the case of IT portfolios, IT projects are similar to NPD and R&D projects, in terms of project cost being the primary concern. The application and infrastructure assets that result from projects are similar to financial assets, in that one can think in terms of acquisition costs (could be the same as project costs), holding (or support) costs, and disposal costs for these assets.

Support (or holding, or management) costs for IT application and infrastructure assets have some important characteristics, which need to be emphasized. While support costs are typically a relatively small percentage of asset value in the case of financial assets, they can be a significant portion of total costs in the case of some application and infrastructure assets, and need to be carefully managed.

In the case of financial assets, organizations are not interested in tracking support costs for each individual asset. However, in the case of IT assets, organizations often incur significant infrastructure and support costs. Hence, they would like to assign these costs to different departments or user organizations. Chargeback or cost allocation systems are used for this purpose. Also, costs of one asset class (e.g., application or project) are related to those of another asset class (e.g., infrastructure), and hence, calculating total costs of an application or project might require some way of allocating or charging back cost of infrastructure assets to applications or projects. Chargeback of IT costs to users is a controversial topic, and user departments are not always satisfied with chargeback mechanisms and the behavior modifications that they induce (Drury, 2000). However, organizations continue to use chargeback systems (Quinlan, 2002), and with the growing trend towards IT being delivered as a service, it is likely that innovative methods of assigning shared costs of infrastructure to applications and users (Gerlach, Neuman, Moldauer, Argo, & Frisby, 2002; Hoffman, 2005) merit additional research (Thornton, 2005).

Risk

Risk is often viewed as the possibility of deviation from an expected outcome (Wallace et al., 2004). Financial, NPD, R&D, and IT portfolios differ in terms of the magnitude and relative importance of different types of risks. Risks have been extensively studied in the financial domain, and are typically classified into market or systematic risks, and private or unsystematic risks. Market risk factors are typically correlated with the risks to the overall financial market, and include major economic factors such consumer confidence, oil prices, and interest rates. Market risk can be hedged by holding a diversified portfolio of securities. Private risk, on the other hand, is specific to individual projects, and is the result of factors that are not correlated with market risk. These include technical risks, project management risks, and organizational risks.

NPD portfolios typically have a significantly higher market risk compared to R&D portfolios, which have a significantly higher private risk (often technical risk). Risk factors of IT portfolios are likely to be primarily private risks. Also, the definition of risk and relevant risk factors could vary for project, application, and infrastructure subportfolios.

Risk, in the context of IT projects, can be defined as the possibility of an unfavorable outcome in terms of time, cost, or functionality of the final project deliverable (Wallace & Keil, 2004). There is an extensive body of literature on identifying risk factors for IT projects (Schmidt et al., 2001), and managing risk in IT projects (Schmidt, Lyytinen, K., Keil, & Cule, 2002; Wallace et al., 2004; Wallace et al., 2004; Westerman, 2005; Westerman & Walpole, 2005).

This article defines risk in the context of IT applications as *the likelihood of the application not delivering the expected business benefits*. Application risk factors include the risk of low adoption and use, and risk of application downtime. Risk of low rates of application adoption and use is often the result of behavioral factors and related to the MIS literature on IT adoption (Venkatesh et al., 2003) and IT success (DeLone & McLean, 2003). Risk of application downtime could be related to security risks (Arora, Hall, Pinto, Ramsey, & Telang, 2004; Rainer, Snyder, Carr, & Houston, 1991; Sun, Srivastava, & Mock, 2006). It is important to note that there is a need for research that focuses on IT application risk from an integrated perspective that includes all types of IT assets.

Infrastructure risk can be defined in a manner similar to application risk as *the likelihood of the infrastructure not delivering the desired business benefits*. However, the business benefits of infrastructures are more difficult to measure when compared to those of applications. Infrastructure risks include natural disasters, terrorist attacks, power failure, software bugs, etc (Arora et al., 2004; Rainer et al., 1991; Sun et al., 2006). Thus, while risk has been studied in some contexts (e.g., project risk), IT risk management is an underdeveloped area, and there is a need for additional research that examines risk management in IT from an integrated perspective, and examines the relationships between project, application, and infrastructure risks. There is a growing recognition that IT risk management may be a valuable organizational capability (Westerman, 2005; Westerman & Walpole, 2005). Other disciplines such as operations management recognize the fact that risk management in their discipline is underdeveloped and encourage additional research in this area (Seshadri & Subrahmanyam, 2005).

Interdependencies

In general, interdependencies refer to situations where characteristics (alignment, benefits, costs, risks) of a portfolio asset depend on characteristics of another asset. Interdependencies have a major impact on the value of an IT portfolio over time. Interdependencies between assets have been extensively researched in finance. Project interdependencies have also been studied in NPD, R&D, and IT research. The relationship between projects may be positive (complement), negative (substitute), or zero (neutral) (Chien, 2002; Devinney & Stewart, 1988). Chien (2002) identified four types of interrelationships among projects: outcome or technical, cost or resource-utilization, impact or benefit, and serial (present-value) interrelationships. Outcome interrelationships occur when a project outcome depends on the other projects outcomes. Cost interrelationships exist in a portfolio when the total cost of the portfolio cannot be represented as the sum of the costs of the individual projects. Benefit interrelationships among the projects in a portfolio make the payoffs of the projects not additive. Serial interrelationships arise when time is considered as a factor in selecting the projects in a portfolio. Santhanam and Krypakis (1996) discussed three types of interdependencies involving IT projects: resource, benefit, and technical. Resource dependencies involve shared resources such as hardware and software. Benefit interdependencies arise when projects are synergistic. Technical dependencies arise when completion of one project is dependant on completion of other projects, due to technical reasons.

The MIS literature differentiates between hard and soft dependencies (Bardhan & Sougstad, 2004). Hard dependencies exist when a capability developed for one project is required by one or more other projects. Soft dependencies are when a capability from one project supports or enhances capabilities of other projects. In general, however, the concept of interdependencies between different types of IT assets is underresearched in MIS, but extremely important if IT is to be managed as a portfolio of assets. Table 2 summarizes different types of interdependencies between IT assets. For example, Cell 1 in Table 2 indicates that new project proposals may depend on other approved and in-progress projects for shared resources (e.g., a common server or storage area network). It may also be possible that a new project proposal depends on some other project for shared benefits (an e-commerce project might depend on the completion of an infrastructure upgrade project for enhanced benefits). Cell 7 indicates a different type of dependency. An existing infrastructure component (e.g., server) might

Table 2. Interdependencies between IT portfolio components

	(Other) Approved and In-Progress Projects	**(Other) Existing Applications**	**(Other) Existing Infrastructure components**
New Project Proposals (depend on)	[1] For Shared resources Shared benefits	[2]For Shared resources Inputs (Application outputs)	[3]For Shared resources Inputs (Infrastructure outputs)
Existing Application (depends on)	[4] For Risk Reduction Reduced cost Benefit increase	[5] For Shared resources Inputs (application outputs)	[6]For Shared resources Inputs (infrastructure outputs)
Existing Infrastructure (depends on)	[7]For Risk Reduction Cost Reduction Benefit Increase	[8] For Shared resources	[9] For Shared Resources Inputs

depend on a proposed security project for risk reduction. Similarly, the infrastructure might depend on an in-progress server consolidation project for cost reduction.

These interdependencies are also shown in Figure 2. Shared resources could include hardware, software, or personnel. A detailed analysis of different types of dependencies and their impact on ITPM decisions is an interesting research area. Other disciplines such as R&D management have recognized the need to understand dependencies in greater detail, and contain qualitative (Verma & Sinha, 2002), as well as quantitative studies (Dickinson et al., 2001) that result in improved understanding of different types of dependencies.

This section has summarized key issues in understanding ITPM. A comparison of major ITPM issues with other types of portfolio management is provided in Table 3. This table provides a comparative overview of different type of portfolio management and references to appropriate pages for additional detail.

ITPM DECISIONS AND PROCESSES

Implementing ITPM in organizations involves several interrelated business processes, such as processes for business case development, IS planning, and project management. Many organizations are likely to have some of these processes in place. Hence, it is possible to think of organizations being at different levels of maturity, as far as ITPM is concerned (Jeffery & Leliveld, 2004). This section presents a framework for understanding the relationships between different decisions that are part of ITPM. This framework was derived from the literature review by means of the following process:

a. First, different types of decisions relating to individual assets were identified from the MIS literature (e.g., project selection decisions).
b. Second, decisions relating to portfolios of IT assets (e.g., managing groups of projects) were identified from the NPD, R&D, finance, and MIS research.

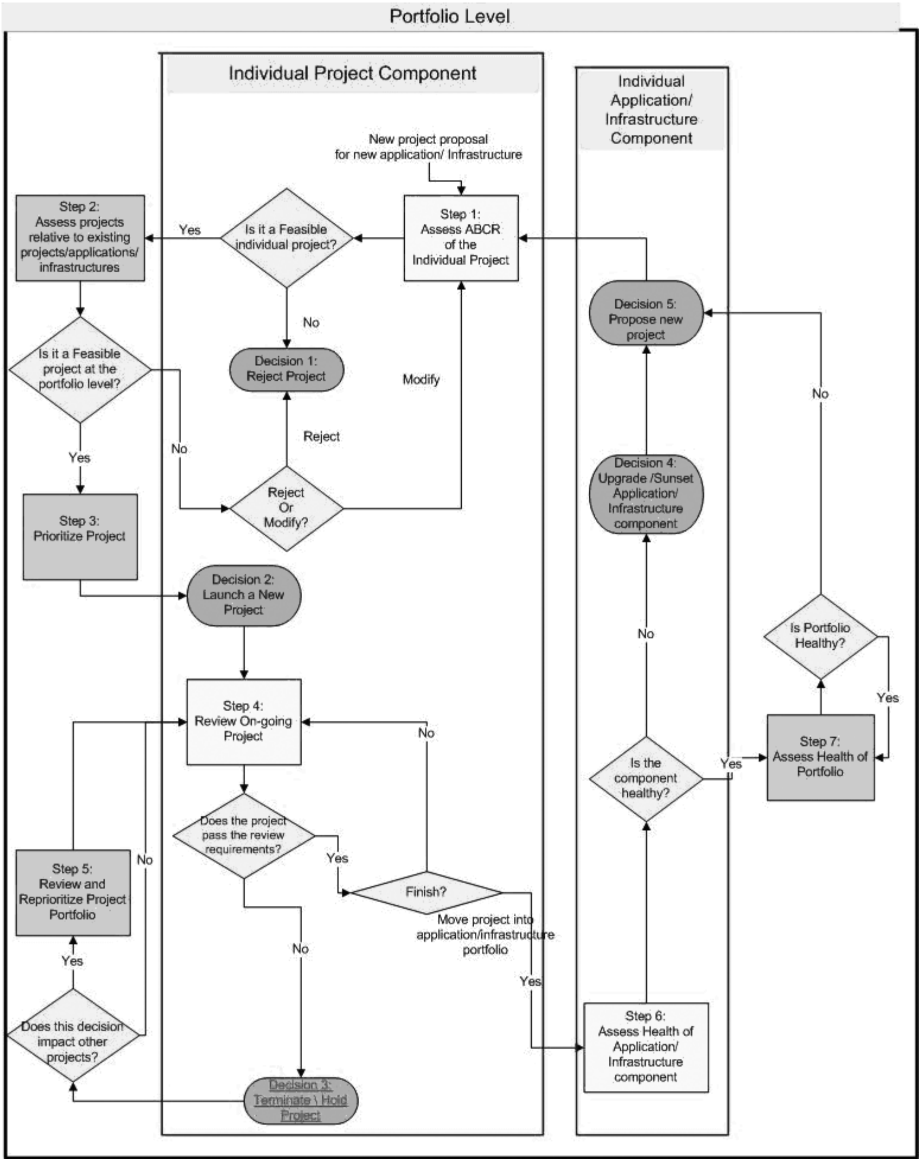
Table 3. A comparison of different types of portfolio management

Topic	Description	Page #
Asset classes	FPM: Different types of stocks, and bonds NPD and R&D: Projects ITPM: Projects, applications and infrastructure components	69
Management Model	FPM: Groups of specialists manage different types of assets (stocks, bonds etc.). NPD: Managed by multi-functional teams R&D: Managed by specialists ITPM: Specialized groups manage different types of assets (applications, projects, and infrastructure) with some overlap. Other business departments have different degrees of involvement depending on how IT governance is implemented.	69
Strategic Alignment	All four types of portfolio management (FPM, NPD, R&D, ITPM) emphasize the need to align the portfolio with long-term goals or organizational strategies	70
Process Change Impact	FPM, NPD and R&D typically focus on a few products or processes. ITPM investments relate to a variety of processes or products depending on project and application portfolios (sometimes involve the entire organization—enterprise wide system)	70

c. Finally, relationships between different types of decisions (involving individual as well as portfolios) were iteratively developed through discussions between multiple researchers, and constant comparison with relationships discussed in the literature. For example, identifying new projects based on the health of a portfolio (relationship between Step 5 and Decision 7 in Figure 3) is discussed in Weill and Vitale (1999).

The following discussion also summarizes ideas from NPD, R&D, and MIS research that are relevant to each of the steps. The ITPM

Figure 3. A framework for understanding major steps and decisions in ITPM



process consists of a series of interrelated steps. One or more steps could result in major ITPM decisions. The ITPM process consists of steps and decisions that pertain to *individual project components* of the portfolio (Step 1, Step 4, Decisions 1-3), steps and decisions that pertain to *individual application or infrastructure components* (Step 6, Decision 4), and steps and decisions that pertain to *the IT portfolio* (steps 2,3,5,7, and Decision 5). *While some of the steps in the framework are well-known, the combination of steps and decisions presented in Figure 2 represents a holistic process-oriented view of ITPM that is likely to be of value to researchers as well as managers.*

Step1: Assess Alignment, Benefit, Cost, and Risk (ABCR) of Individual Projects

Ideas for IT projects[2] could be generated in multiple ways, depending on how IT governance is implemented (Weill, 2004). Sources of project ideas include the SISP process, business users, and IT personnel. A variety of approaches for evaluating individual projects have been proposed in the NPD, R&D, and MIS literature. These include traditional financial evaluation techniques, such as net present value, newer financial evaluation techniques, such as real options (Benaroch & Kauffman, 1999; Santos, 1991), the balanced scorecard (Martinsons, Davison, & Tse, 1999), as well as other techniques (Ross & Beath, 2002).

Traditional financial evaluation methods typically consider benefits and costs, but often underestimate the value of projects (Benaroch & Kauffman, 1999). Newer financial evaluation methods, such as real options, capture managerial flexibility in investment decisions (Benaroch & Kauffman, 1999), as well as uncertainty in cash flows (risk). However, parameter estimation is difficult. Scoring models or balanced scorecards can be used to capture strategic benefits (Martinsons et al., 1999). There is scope for additional research on newer and better methods of evaluating individual IT projects. It is important to note that feasibility in the context of the framework depends on the specific organization, and could be a combination of economic, technical, operational, legal, and ethical factors.

Step 2: Assess Project Fit Relative to Existing Applications/Infrastructures

Projects that are feasible in Step 1 need to be examined, relative to an organization's existing IT portfolio components (project, application, and infrastructure components). This type of analysis is best done by a committee made up of individuals from different business and IT units (ITPM Committee). In this step, organizations may reject or request modification of project proposals. Reasons for project modification or rejection could include similarity with existing IT portfolio components (redundancy), incompatibility with infrastructure standards, incompatibility with existing portfolio components, improved alignment with existing IT portfolio, and other actions that could enhance alignment, or benefit or reduce cost or risk of the IT portfolio. The committee may need to consider a variety of interdependencies between the proposed project and the existing IT portfolio (Table 2) and decide that the original project justification needs to be modified, since the individuals proposing the project were not aware of all the interdependencies. For example, the proposed project could have synergies with existing ITP components, thus reducing project cost and making the project more attractive. If, for example, a new portal project requires a Web infrastructure that is missing from the infrastructure subportfolio, then the project might be rejected or postponed until the infrastructure is acquired through a new project proposal. This step could be complicated and could benefit from additional research.

Step 3: Prioritize Projects

Feasible projects can be prioritized using single criteria methods, based on a financial calculation, or using multiple criteria methods. Project prioritization has been extensively researched, and a variety of approaches have been proposed in the MIS, NPD, and R&D literature (Chien, 2002; Cooper et al., 1997; Dickinson, et al., 2001; Liberatore & Stylianou, 1995a; Liberatore & Stylianou, 1995b; Stummer & Heidenberger, 2003). These include scoring models, analytical hierarchy process, expert systems, mathematical programming, and hybrid methods that do not consider project interdependencies. More sophisticated methods consider interdependencies between projects. The R&D and NPD literature contains several approaches that consider interdependencies (Dickinson et al., 2001; Stummer & Heidenberger, 2003). Research on interdependent project selection and ranking in the MIS literature is limited. Santhanam and Krypakis (1996) propose a nonlinear programming model that considers resource, benefit, and technical interdependencies between projects. Bardhan and Sougstad (2004) present a dynamic programming model that considers hard and soft project dependencies in prioritizing projects. There is considerable scope for additional research that examines the applicability of approaches proposed in the context of R&D or NPD to IT projects, and further development of other methods that consider project interdependencies. In addition to modeling-oriented research, qualitative research that illustrates different types of interdependencies and how to manage them (Verma & Sinha, 2002) will be useful.

Step 4: Review On-Going (Individual) Projects

Projects which pass individual and portfolio-level examination will be accepted and moved to the implementation phase. Projects need to be actively managed to ensure results that are measured in terms of process and product outcomes (Wallace & Keil, 2004; Wallace et al., 2004a; Wallace et al., 2004b). IT projects are considered particularly difficult to manage, and there is an extensive body of literature on IT project management (Wallace & Keil, 2004; Wallace et al., 2004). Similar streams of research exist in the areas of R&D project management and NPD project management (Nobeoka & Cusumano, 1995; Santiago & Bifano, 2005). Termination of ongoing projects is often difficult, due to factors such as escalation of commitment (Keil, 1995; Keil & Mann, 1997; Keil, Truex, & Mixon, 1995). A study of methods to deescalate commitment to failing projects (Keil & Robey, 1999; Montealegre & Keil, 2000) is an interesting research area.

Step 5: Review and Reprioritize Projects in the Portfolio

Business changes, technology changes, and a variety of project risks (Schmidt et al., 2002) result in projects being delayed, terminated, or refocused. Such changes impact other projects, as well as resource availability. IT managers are, therefore, faced with the need to rebalance their portfolio of projects dynamically (in relation to changes in some projects in the portfolio). While there is considerable research on individual IT projects, rebalancing IT portfolios in response to changes in individual projects is an underdeveloped research area. This step is similar to Step 3, in terms of evaluating interdependencies between projects. However, there are likely to be several resource reallocation decisions involved in addition to reprioritizing projects. These resource reallocation decisions should be based on a systematic analysis of the status of existing projects and possible new projects. However, such systematic analysis could be extremely complex. Also, since IT impacts almost every business process, unlike R&D and NPD, there are likely to be a larger number of IT projects, and a greater need for project reprioritization. Hence, IT portfolios are similar to financial portfolios with actively traded assets and a large number of buy and sell transactions due to—or in anticipation of—market changes. In actively traded financial portfolios, managers must frequently make decisions about reallocation of financial resources generated by sell transactions. In IT portfolios, managers must frequently make decisions about reallocation of resources as a result of cancelled, delayed, or refocused IT projects. However, the number and types of resources and their interdependencies involved in IT portfolio reprioritizations are likely to be greater than in the case of financial portfolios. Project reprioritization in MIS is an underresearched area that lends itself to modeling, as well as empirical studies.

Step 6: Assess the Health of Application/ Infrastructure Components

Completed projects result in applications or infrastructure components or systems. An application or infrastructure component could be considered unhealthy, because it is not aligned with organizational goals, does not produce significant organizational benefits, is too expensive to maintain, too risky, or due to a combination of these factors. The MIS literature emphasizes the fact that systems resulting from completed projects may not be used as originally planned. There is extensive literature on IT adoption and use (Jasperson, Carte, Saunders, Butler, Croes, & Zheng, 2002; Jasperson et al., 2005; Venkatesh et al., 2003) and IT success (DeLone & McLean, 2003). System use problems can be provided by system users or technical support personnel through periodic surveys and/or analysis of technical support calls. It is important to have processes in place to systematically analyze the health of applications or infrastructure components. MIS literature in this area is limited. Weill and Vitale (1999) illustrate the use of risk return bubble diagrams to analyze the health of an application portfolio. Interesting research issues in this area include defining health of applications and infrastructure components, and designing processes and metrics to assess health. Validation and extension of existing models of adoption and use is relevant to this step.

Step 7: Assess the Health of Portfolio and Balance

Assessing health of the IT portfolio considers different types of interdependencies in analyzing ABCR of the portfolio (unlike Step 2, which only considers dependencies involving a proposed project). Table 4 illustrates how different types of dependencies apply to different steps in the ITPM framework. For example, project-project (PP), project-application (PA), and project-infrastructure (PI) dependencies are relevant during Steps 2 and 5.

This step is closely related to SISP (Grover & Segars, 2005). Approaches such as critical success factors or value chain analysis can be used as part of the assessment. However, SISP methodologies often focus on alignment and benefits, and do not integrate cost and risk. There is an increasing emphasis on the risk of an organization's IT portfolio as a result of increased organizational dependence on IT, and increased likelihood of security attacks. Issues such as threat assessment, disaster recovery planning, and regulatory compliance are part of this step. Organizational performance and increasing emphasis on the business value of IT (Carr, 2003) could drive projects to reduce the cost of the IT portfolio.

Managers may be interested in knowing what the total support costs of the portfolio are, which applications are the most expensive to support, which are the most risky applications are, or what the risk-return characteristics of applications are, or what the major risks of the portfolio are, and how they can be mitigated as part of ITP balancing. Additional research which guides balancing decisions is required.

The results of portfolio health assessment could be portfolio balancing decisions to upgrade or sunset applications or other types of projects. It is important to realize that unlike IT portfolios, where assets can be disposed of relatively easily, there is significant cost associated with implementing IT portfolio balancing decisions. Besides hardware and software costs, such balancing decisions could include costs of personnel reassignment and training. There is considerable scope for additional research on integrated approaches to assessing the health of an IT portfolio and balancing the portfolio based on health assessment. Such approaches should consider alignment, benefits, costs, and interdependencies.

Table 4. Dependencies during different steps in the ITPM framework

	P	A	I
P	Step 2,5	Step 2,5	Step 2,5
A	Step 7	Step 7	Step 7
I	Step 7		Step 7

P: Project; A: Application; I: Infrastructure

ILLUSTRATIVE EXAMPLE

This section provides a brief example to illustrate how managers might use the ITPM Decision Framework in Figure 3. DigiBank is a major financial institution. The CEO and CIO of the organization have seen some articles about ITPM, and believe they could benefit from better managing their IT assets through ITPM. DigiBank has some processes in place for managing IT assets. However, the CEO and CIO believe there is considerable scope for more systematic management of IT assets. They are unsure about what constitutes ITPM, how it is different from what they are doing now, and what is involved in implementing ITPM.

Figure 3 presents a process which the CIO or (other managers) can use to systematically question existing IT management processes, identify strengths and weaknesses in existing processes and put in place additional processes needed to implement ITPM.

The process (Figure 3) starts with ensuring that each project that is proposed has a measure of alignment, costs, benefits, and risks (Step 1). The CIO realizes that Digibank has some processes for measuring project costs and benefits. Processes for measuring project risk exist, but need improvement. Processes for measuring project alignment need to be created. The discussion and references in Section 4 provide a starting point for improving project risk and alignment measurement.

On reviewing Steps 2 and 3 the CIO realizes the need to improve processes for comparing all proposed projects. They initiate a review of existing processes relating to these steps. The references relating to Steps 2 and 3 provide a starting point for fresh ideas. The CIO believes Digbank has good processes for project review (Step 4). However, decisions for project termination are not always consistent and could be improved, as is the case for reviewing and reprioritizing a portfolio of projects (Step 5). Digibank has a checklist and processes for Step 6. However, the CIO feels that decision making regarding upgrading or sunsetting a project could be improved. There are no processes in place for assessing the health of a portfolio of applications (Step 7) and references in Section 4, such as (Weill & Vitale, 1999) are a good starting point.

Having completed this exercise, the CIO of DigiBank feels that without Figure 3, systematic review of key steps and decisions needed to implement ITPM would have been considerably more difficult and would not have considered all the steps and decisions. Such a systematic review helps organizations assess their existing processes, relative to decisions and processes required for ITPM, and help them plan for ITPM implementations.

MANAGERIAL ISSUES

Practitioner articles regarding ITPM (Leliveld & Jeffery, 2003; Maizlish & Handler, 2005) mention that several organizations have implemented ITPM to varying degrees (maturity levels). Weill and Aral (2006) suggest that ITPM is a best practice. Surveys of chief information officers (Leliveld & Jeffery, 2003) regarding ITPM implementation reveal several managerial issues and challenges in implementing ITPM. Some interesting managerial issues for which related MIS literature in other implementation contexts exists are discussed below.

Management Support and IT Governance

ITPM projects are enterprise projects, because they involve multiple departments in addition to IT. Even within IT, there are likely to be different stakeholder groups, such as project managers, application support personnel, architects, and administration personnel with access to cost and contracting responsibilities involved in an ITPM project. Also, ITPM projects can be perceived as IT projects and not business projects. While benefits to IT from a successful ITPM implementation may be expected, business units may be unclear as to why they should support an ITPM project. Successful ITPM projects are likely to require senior management or CXO (CEO, CFO, COO, and CIO) level support in order to resolve conflicts and ensure project success. Hence, the role of senior management and how they demonstrate support for ITPM is an interesting area of research. Prior research has recognized that power structures within an organization influence the type of senior management support required (Jasperson et al., 2002). How ITPM fits within an overall IT Governance framework, and roles and responsibilities of personnel involved in ITPM, is an interesting research area. This could build upon existing MIS literature on senior management support, and IT governance in other contexts (Brown & Grant, 2005; Peterson, 2004; Rau, 2004; Weill & Ross, 2005).

Relationship between IT and Business

Successful ITPM projects are likely to involve significant interaction between IT and business. These interactions are likely to occur during ITPM implementation as well as during ongoing management of the IT portfolio. Hence, recognizing differences between IT and business (Bassellier & Benbasat, 2004; Keil, Tiwana, & Bush, 2002; Peppard, 2001) and improving trust (Bushell, 2004; Gefen, 2004) are likely to be important in ensuring success of ITPM implementations. It is important to note that different stakeholders (e.g., business units, IT subunits) in an ITPM implementation may prefer outcomes (in terms of project selection or prioritization) that are best for them, while successful ITPM implementation is aimed at decisions that are best for the organization as a whole. This is likely to lead to conflicts between subunits. Hence, issues of power and politics are also likely to be important (Davenport, Eccles, & Prusak, 1992; Hart & Saunders, 1997; Jasperson et al., 2002) for a variety of portfolio management decisions. Power and politics are also extremely important, because successful ITPM implementation requires sharing a variety of data across departmental boundaries. Examples of such data include cost data, contract clauses, application and infrastructure performance data, and project risk and success data.

Organizational Readiness and Change Management

Successful ITPM implementation in organizations could change several IT-related decision making processes in organizations. Examples of such processes include strategic planning, budgeting, project management processes, risk management processes, and application support processes. Hence, implementing ITPM can be viewed as business process change (Kettinger & Grover, 1995). Organizations differ significantly in their readiness to change (Guha, Groven, Kettinger, & Teng, 1997) and successful ITPM implementations are likely to involve active change management.

While a variety of research approaches are useful in studying managerial issues related to ITPM, case studies of ITPM implementations would be a particularly interesting and valuable area of future research. Such case studies would help to better understand "how" and "why" issues related to ITPM implementation (Yin, 1994).

CONCLUSION

The concept of managing IT as a portfolio of assets is gaining momentum, and is beginning to be considered a best practice (Jeffery & Leliveld, 2004). However, an analysis of what an IT portfolio is, how it is related to other types of portfolios, and how it should be managed is underdeveloped in MIS research. This article represents an attempt to present a cumulative body of relevant knowledge to aid future development of ITPM.

This article makes several contributions. First, it compares ITPM with other types of portfolio management, and develops an improved understanding of IT assets and their

Table 5. Summary of directions for future research

#	Directions for future ITPM Research	Page #
1	Methods of specifying the values of portfolio components	71-72
2	Improved methods of assigning shared costs of infrastructure to applications and users	72
3	Studies of risk management in IT from an integrated perspective and examines the relationships between project, application, and infrastructure risks	73
4	Qualitative and quantitative research on characterization and management of different types of interdependencies between different types of IT assets	74-75
5	Newer and better methods of evaluating the feasibility of individual IT projects	77
6	Additional research on methods to deescalate commitment to failing projects.	78
7	How to rebalance IT project portfolios in response to changes in individual projects.	78
8	Validation and extension of models of IT adoption and use	79
9	Comprehensive health assessment of IT assets	79
10	How ITPM fits within an overall IT Governance framework and roles and responsibilities of personnel involved in ITPM	80-81
11	The role of senior management in supporting ITPM	81
12	Issues of power and politics in ITPM decisions	81
13	Case studies of ITPM implementations	81

characteristics. A review of relevant literature from multiple disciplines is used to develop an improved understanding of ITPM concepts, such as assets, alignment, costs, benefits, risks, and interdependencies. Second, it presents a systematic, process-oriented framework for understanding ITPM. The proposed framework identifies critical ITPM decision stages. This framework could be of use to practitioners of ITPM who are interested in effective ITPM implementations in organizations, as well as researchers who are interested in further theoretical development of ITPM. An illustrative example of the use of this framework is provided. Third, the article integrates ideas from other types of portfolio management, as well as different streams of MIS research into ITPM decisions and management of ITPM implementations. This integration of research streams helps to identify a cumulative body of ITPM-related knowledge that exists and facilitates further development of ITPM. Several ideas for future ITPM research (summarized in Table 5) are identified.

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ENDNOTES

1 Our discussion of asset classes and sub-portfolios (projects, applications, infrastructure components) is different from that of Broadbent and Weill (1998) who classify IT investments as infrastructure, transactional, informational, or strategic. Our approach is analogous to classifying financial portfolios as consisting of stock, bond and cash assets or sub-portfolios. Broadbent and Weill's approach is similar to classifying financial portfolios as conservative, balanced, and aggressive. Both approaches to classifying portfolios are used.

2 A project proposal can be a request to build a new application/infrastructure component or an upgrade request for a current infrastructure/application component.

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