ASSESSING THE PAYOFF FROM AN INFORMATION TECHNOLOGY INFRASTRUCTURE: A MULTI-PHASED APPROACH

Lara Preiser-Houy *

The key managerial challenge associated with providing an information technology (IT) infrastructure is to be able to ascertain the economic viability of infrastructure investments. Such investments appear to be on the increase as we move into the latter half of this decade. Yet to date, very little is known about the impacts infrastructure resources have on organizational performance and the ways in which these impacts could be measured. The lack of guidelines on how to assess the infrastructure payoff presents a problem for the Information Systems (IS) managers charged with the task of providing an effective foundation for the organizational business processes.

An approach to assess the economic viability of infrastructure resources presented in this paper is aimed at helping IS and general managers make more informed decisions as to their infrastructure investments. The proposed approach consists of the three phases -- identifying infrastructure value sources, assessing the cost and value of the firm's installed infrastructure resources, and justifying additional infrastructure expenditures. The application of the proposed approach to the infrastructure investment decisions is one of the first steps towards addressing the managerial challenge of providing a robust foundation for the firm's business activities.

One of the key responsibilities of an Information Systems (IS) function in the late 1990s will be the development and maintenance of a technological highway that enables multifunctional systems to support the networked organizational society (Rockart, 1992). This technological highway is an information technology (IT) infrastructure. In fact, a survey of top IS managers suggests that developing and managing IT infrastructure resources is one of the ten

* *Lara Preiser-Houy is an Assistant Professor at the California State Polytechnic University, Pomona, CA.*

Manuscript received May, 1996, revised July, 1996.

critical tasks facing the IS function in the 1990s (Niederman et at., 1991). However, the management of infrastructure resources is quite a challenge in light of the changing technological and business environments. The key challenges associated with building and sustaining an effective IT infrastructure are technical as well as managerial.

On a technical level, one of the challenges is to provide functional, efficient and easily maintainable IT infrastructure (Davenport and Linder, 1994). Furthermore, managers are faced with the challenge of matching infrastructure's technical sophistication to the role infrastructure resources play in an organization (Weill et al., 1993). On a managerial level, the key challenges are to identify the benefits derived from infrastructure investments, to measure such benefits, and to justify additional infrastructure expenditures (McKay and Brockway, 1989; Weill, 1992a).

Preliminary results of an empirical investigation of infrastructure investments show not only that such expenditures represent a large component of an overall IT budget (i.e., 46 percent of total IT expenditures), but that the infrastructure investments appear to be increasing at the rate of 9.5 percent per annum (Weill et al., 1995). Yet to date, the literature provides very few guidelines on how to measure the value of such investments. One of the possible reasons for the lack of empirical investigations in this area is the difficulty of measuring the infrastructure benefits. The questions of how to justify flexibility or the future ability of an organization to respond quickly to competitive thrusts require answers, yet such answers are hard to come by. Hence, the current practices of measuring the value of an IT infrastructure appear to be more like an art that depends on "gut feel" and experience rather than on science. This lack of reliable measures as to infrastructure value makes it difficult for managers to justify additional investments in infrastructure. Yet, the increasing rate of infrastructure-related expenditures points to the need to find meaningful ways to identify and measure the value derived from infrastructure resources.

Purpose Of This Paper

The purpose of this paper is to present a multi-phased approach to assessing the economic viability of IT infrastructure investments. Specifically, the paper addresses three important questions related to the managerial challenge of providing an IT infrastructure. These questions are: (1) How does IT infrastructure provide value? (2) How does the firm assess the business value of its firm's installed infrastructure resources? and (3) How does the firm justify additional investments in an IT infrastructure?

This paper first provides a comprehensive definition of an IT infrastructure. Next, it discusses the ways in which IT infrastructure may provide value to an organization. Then, it discusses a method to assess the business value of the firm's existing infrastructure resources. Finally, it presents three methods for justifying additional infrastructure expenditures.

DEFINITION OF AN INFORMATION TECHNOLOGY INFRASTRUCTURE

The topic of an IT infrastructure is not a new one. For example, in the IT planning literature, at least five different authors discuss IT infrastructure in articles published between 1970 and 1984 (Boynton and Zmud, 1987).

1. Weill (1992a) defines an IT infrastructure as "the base foundation of IT capability <u>budgeted for and provided</u> by the information systems function and shared across multiple business units or functional areas. The IT capability includes both the technical and managerial expertise required to provide reliable services" (p. 8).
2. Davenport and Linder (1994) also suggest that an IT infrastructure consists of both technical and human components which are shared throughout the organization (Table 1).
3. Hoffman (1994) views an IT infrastructure as a set of technical and human resources that enable the organizational IT activities to take place.

Building upon the definitions of an IT infrastructure provided by Weill (1992a), Davenport and Linder (1994), and Hoffman (1994), an IT infrastructure may be conceptualized as an integrated set of technical components coupled with human skills and expertise to form a shared foundation for enabling IT-related activities that support an organization at the firm and business unit levels. Figure 1 depicts this conceptual view of an IT infrastructure. Table 2 provides a more detailed view of infrastructure components.

Table 1
Davenport and Linder's (1994) Five-Layer Model of an IT Infrastructure

IT Infrastructure Layer	Technical Component	Human Component
Core Technologies	Wires and Boxes	Basic Technical Skills
Technical Functionality	Platforms and Utilities	General Computing and Networking Skills
Business Applications	Common Applications	Application Development and Use Skills
Business Information	Shared Data	Information Management and Use Skills
Business Process Support	IT Enablement of Business Processes	Process Design and Execution Skills

Summary

An IT infrastructure is an enabling foundation for the firm and business unit IT activities of an organization. Such activities may, for example, include construction and operation of object-oriented application systems, provision of architectural standards for data, information, platforms and communication networks, as well as the provision of a secure IT environment throughout the firm. The IT activities enabled by the technical and human components of an IT infrastructure lead to the development and operation of applications that in turn provide business capabilities such as, interactive order-processing or materials planning and acquisitions.

The conceptual framework of an IT infrastructure presented in Figure 1 suggests that infrastructure resources impact organizational performance indirectly by enabling applications that provide business value. Thus, before the benefits derived from an IT infrastructure can be measured, it is important to understand the process of how infrastructure creates value. The next section addresses this topic in more detail.

VALUE PROVIDED BY AN IT INFRASTRUCTURE

Issues / Problems with Measuring the Infrastructure Value

IT infrastructure expenditures appear to grow from year to year as evidenced by preliminary research conducted by Weill et al. (1995) . Yet empirical studies of Chief Information Officers suggest that business leaders are not quite satisfied with the currently used practices to assess the actual payoff from their investments in technology (Wilson, 1993). To date, empirical findings of IT payoffs suggest that little is known about the actual effects IT capital investments have on organizational performance (Brynsjolfsson and Hitt, 1993). Unfortunately, even less is known about the payoffs from infrastructure investments, since empirical studies of IT value do not differentiate between infrastructure and other types of IT assets. Possible reasons for the lack of studies in this area is the difficulty of measuring the payoff derived from infrastructure resources. Measuring the value of an IT infrastructure is a difficult task because of the following:

- IT infrastructure generates indirect, qualitative and at times uncertain benefits that can not always be easily measured using the traditional capital budgeting techniques (Weill, 1992a). For example, the benefits like increased flexibility, availability of real-time information to geographically-dispersed business entities, better architectural standards, just to list a few, are difficult to qualify and tie directly to the firm's performance. Moreover, since the infrastructure investments are far removed from the performance benefits, many other factors like economy, industry structure, and firm's competitive position, may impact the relationship between the infrastructure investment and the firm's performance (Weill, 1992a).

- IT infrastructure provides value to many different "communities of interest" (i.e., functions, departments, business units) and thus supports many different business purposes (McKay and Brockway, 1989). Moreover, different stakeholders may view the value derived from an IT infrastructure from different perspectives. For example, business unit developers may perceive firm-wide data architectural standards as constraining and potentially not useful, while corporate developers may argue that the realistic value of such standards has a positive value (i.e., the integrity and accuracy of the firm-wide database is 90 percent due to the data architectural standards as opposed to 50 percent accuracy before the standards were implemented).

The above problems suggest that measuring the infrastructure value is a difficult task. To date, few researchers and practitioners have succeeded in identifying the locus of infrastructure impacts and measuring such impacts. Does the lack of evidence as to the positive contribution of an IT infrastructure to organizational performance mean that infrastructure expenditures do not pay off? Brynsjolfsson (1993) once remarked that the "shortfall of evidence" as to the positive contribution of IT to productivity is not necessarily the "evidence of a shortfall" in IT productivity. Mismeasurement of IT inputs and outputs may be at the root of the IT "productivity paradox" dilemma. Similarly, the lack of evidence as to the positive contribution of infrastructure to organizational performance is not necessarily the evidence that infrastructure does not pay off. To uncover the payoff from infrastructure investments, it is important to first understand how an IT infrastructure creates value in an organization, and then to attempt measuring or estimating that value. In the next sub-section, a process model of how infrastructure creates value will be presented.

Toward a Model of an IT Infrastructure Value

The basic aim of the firm's IT infrastructure is to enable the IT activities of an organization. These IT activities ultimately result in planning, building and operating many different applications that support and enhance current operations as well as enable the organization to achieve its strategies. There appear to be five key sources of value provided by an IT infrastructure in enabling the firm's IT activities. These sources of value are as follows:

- economy of scale and leveraging of existing IT investments (McKay and Brockway, 1989; Weill et al., 1993).
  --economies of scale are derived from improved technology utilization, elimination of redundancy, and the standardization of the IT use and management practices.

Figure 1
Conceptual View of an IT Infrastructure

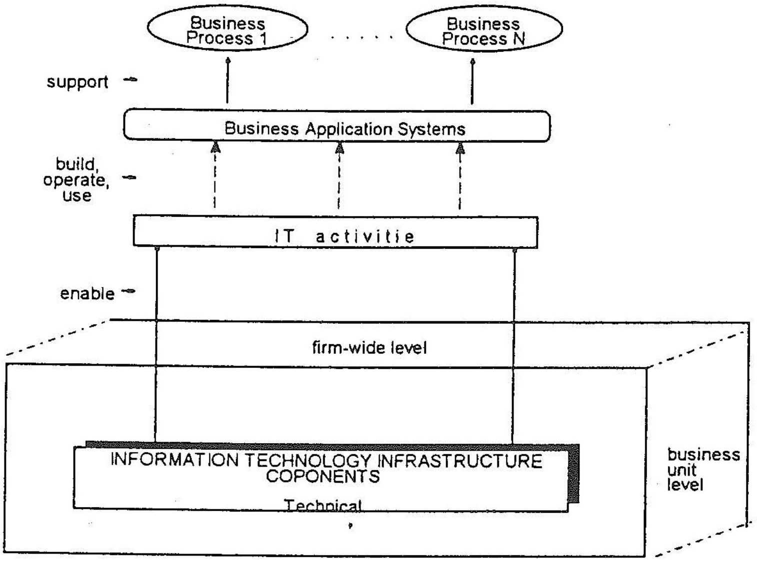


Table 2

Detailed View of IT Infrastructure Components

IT Infrastructure Components	Description
Technology Base	Client/Server Architectures Local and Wire Area Networks Wireless Technology Mainframes/Minis/Micros Systems and Communications Software
Shared IT Services	Applications Development Services (e.g., CASE, 4gls, object tools, project management tools, expert system shells) Data Warehouse Services Network Services
Standards/Security	Architectural Standards for Hardware, Networks, Applications, Data and Information Technical (internal and external) security provisions for networks, data, and applications
IT Human Skills and Expertise	Data Management Application Development Network Administration Standards Setting Training

foundation to build and run business applications that support current strategic intent of an organization (Hoffman, 1994; Weill et al., 1993).

- flexibility to quickly respond to competitive trusts and changing business conditions (Duncan, 1995; Davenport and Linder, 1994; Hoffman, 1994; Weill et al., 1993).
- architectural standardization throughout the organization (Davenport and Linder, 1994; Hoffman, 1994; Weill et al., 1993).
- secure IT environment throughout the organization (Davenport and Linder, 1994; Hoffman, 1994; Weill et al., 1993)..

Empirical observations of infrastructure used in organizations suggest that the expected benefits (i.e., value) derived from infrastructure, the level of infrastructure investment, and the approaches to justify such investments are contingent upon the role infrastructure plays in the organizational context (Weill et al., 1993). Furthermore, the more long-term the role is, the more difficult it is to quantify and assess the value derived from infrastructure resources. Weill et al. (1993) suggest three different views of infrastructure role that may be useful in categorizing infrastructure investments. These roles are "utility", "dependent" and "enabling". (Weill et al., 1993) characterize each role as follows:

- Organizations that view an IT infrastructure as a "utility" consider infrastructure investments to be an administrative overhead expense and justify such expense on the basis of cost savings that result from economies of scale.
- Organizations that view an IT infrastructure as a "dependent" resource consider infrastructure investments to be a business expense and justify such expenses on the basis of how well they enable the current strategy of the firm.
- Organizations that view an IT infrastructure as an "enabling" resource consider infrastructure expenditures to be business investments and justify such investments on the basis of how well they enable current and future flexibility.

The empirical investigation of the relationship between investments in IT and firm performance in the valve manufacturing industry suggests that the effectiveness with which IT expenditures are converted into successful IT use, and not the magnitude of IT spending, is the key to deriving value from such expenditures (Weill, 1992b). Similarly, the results of a preliminary study of IT payoffs in the banking industry show a negative association of IT spending with firm performance and positive association of the accumulated IT assets (i.e., percentage of banking functions computerized) with the performance of large banks (Markus and Soh, 1993). Thus, it appears that the firms benefiting most from their IT spending are the ones that have effective internal processes of converting IT expenditures into a portfolio of applications that provide business functionality to the firm.

The literature reviewed and synthesized so far indicates that the sources of infrastructure value are varied and are contingent upon the way an organization views the role of infrastructure resources. Moreover, the effectiveness with which such expenditures are converted into IT use contributes to the value of infrastructure assets. But how are the infrastructure expenditures actually converted into IT impacts that ultimately lead to improved organizational performance? A process theory model developed by Soh and Markus (1995) may help provide an answer to this question.

Soh and Markus's model is depicted in Figure 2 and described below. It consists of the three distinct, yet tightly coupled processes by which IT creates business value in an organization. Each of these processes is comprised of elements that lead to the transformation of the original IT expenditures into improved organizational performance.

As depicted in Figure 2, the "IT Conversion Process" transforms IT expenditures into IT assets. The activity of managing IT resources influences the effectiveness with which IT expenditures are converted into IT assets which in turn are comprised of business applications, IT infrastructure and user skills (Soh and Markus, 1995). The model, however, does not differentiate between infrastructure-related expenditures and other types of IT investments.

Furthermore, the "IT Use Process" transforms IT assets into IT impacts. Among such impacts are redesigned business processes, improved decision-making at all levels of the organizational hierarchy, and new products and services. This transformation is moderated by the appropriateness of technology use in light of the organizational directives and culture. The model, however, does not differentiate between infrastructure-related IT impacts and other types of impacts.

Finally, the "Competitive Process" transforms IT impacts into improved organizational performance (i.e., productivity, market share). The industry structure, economic conditions and firm's competitive position are the key factors that moderate and influence that transformation.

The process model of IT business value proposed by Soh and Markus (1995) is quite complex and thus difficult to test. That is why the authors suggest to break the model into three sub-processes for the purpose of empirical validation.

The empirical observations of Weill et al. (1993), and the framework of IT value developed by Soh and Markus (1995) provide a foundation upon which the model of how infrastructure expenditures create business value may be developed. This model is depicted in Figure 3. The key characteristics of the proposed Infrastructure value model are as follows:

Figure 2
"How IT Creates Business Value: A Process Theory"
Soh and Markus (1995)

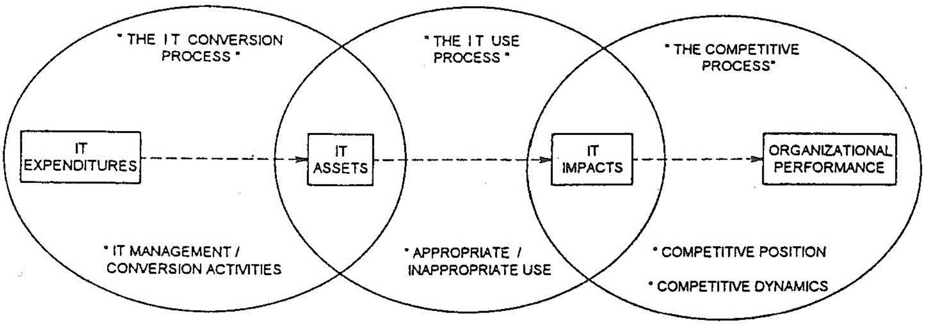
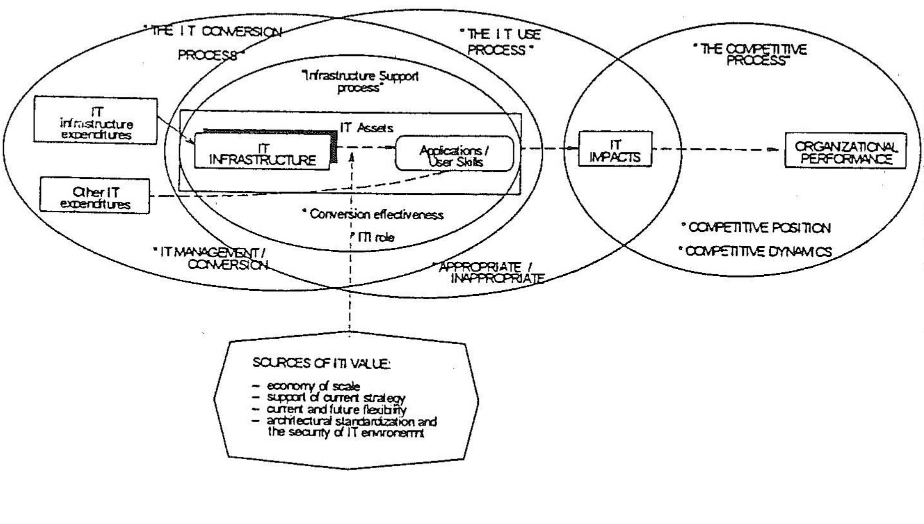


Figure 3
Conceptual Model of How Infrastructure Provides Value



- IT expenditures are subdivided into two categories: infrastructure-related expenditures (e.g., hardware, systems software, communication links, etc.) and non-infrastructure-related expenditures (e.g., non-share application systems).
- IT assets are subdivided into two categories: IT infrastructure (as defined above in the section titled Definition of IT Infrastructure) and business applications coupled with user skills.
- The *Infrastructure Support process* converts the infrastructure assets into business applications. Such conversion takes place when the technology infrastructure enables the IT activities that lead to the development and implementation of business applications. The sources of infrastructure value are economy of scale, support of current strategies, flexibility, architectural standards and secure IT environment. Moreover, the process of converting infrastructure assets into business applications is contingent upon the role of an infrastructure in the organization and the effectiveness with which the infrastructure expenditures are converted into business applications. For example, undercapacity of infrastructure and lack of standards, may negatively influence the processes of building, operating and using business applications.
- Business applications / user skills, and not the IT infrastructure component of IT assets, are transformed into IT impacts.

The model depicted in Figure 3 posits that infrastructure expenditures are converted into infrastructure resources. These resources in turn enable the IT activities of building, operating and using business applications that support the firm and business-unit activities of an organization. Furthermore, business applications and user skills are then transformed into IT impacts that lead to ultimate business value as captured by financial and productivity statistics. The Infrastructure Support process is contingent upon the effectiveness with which the infrastructure assets are converted into business applications and the role played by the infrastructure in an organization.

Summary

In this section I have described how IT infrastructure expenditures create business value in an organization. An IT infrastructure provides value to an organization by enabling the development of applications which support business activities of the firm. The sources of infrastructure value are contingent upon the role infrastructure plays in the organization (i.e., “utility”, “dependent”, “enabling”) and the effectiveness with which the infrastructure assets are converted into an applications portfolio. Once the sources of infrastructure value are identified, the next step is to assess the payoff from the existing infrastructure resources.

A METHOD TO ASSESS THE COST AND VALUE OF THE FIRM'S INSTALLED IT INFRASTRUCTURE RESOURCES

In assessing the payoff from the IT assets, management often looks for answers to the following questions: (1) How well are we doing today?, (2) How well are we positioned to compete in the future? (Wilson, 1993). The answer to the first question requires an understanding of how much the company is currently investing in various infrastructure components and the sources of value for each component. The answer to the second question depends on the level of current infrastructure investments and the role IT infrastructure plays in the organization. If the management determines that the level of current infrastructure investments is relatively low vis-à-vis the role infrastructure plays in the organization, the current infrastructure investment strategy may need to be re-evaluated. For example, if a firm with the "enabling" view of IT infrastructure spends only 2 percent of the total infrastructure investments to support future flexibility, the management would need to develop strategies to justify additional infrastructure-related investments.

One way to assess the cost and value of the firm's installed IT infrastructure resources is to identify how much money was spent on each infrastructure component and to allocate the cost of each component to the various purposes served by the infrastructure in supporting the overall IT activities of the organization (Hoffman, 1994).

The purposes served by an IT infrastructure vary from company to company and depend on how the firm views the sources of infrastructure value. While some organizations may view the key source of infrastructure value to be in supporting the current strategy (i.e., enhancement and operation of current applications), other organizations may view future flexibility as the key source of value to be derived from the infrastructure resources. It is also likely that an IT infrastructure could serves different purposes in the same organization. If that is the case, the senior IS management may need to prioritize the importance of each purpose in light of the company's strategy, and allocate infrastructure expenditures in accordance with the company's goals and objectives.

Table 3 presents an example of infrastructure expenditures allocated to various purposes served by an IT infrastructure in creating value for a hypothetical manufacturing organization with annual revenue of $100 million. The first column of Table 3 details the individual components of an IT infrastructure. The second and third columns list the estimated budget amounts and the percentages of the total budget associated with each infrastructure component. The remaining columns detail the costs of each component allocated to five different purposes served by an IT infrastructure. The purposes served by an IT infrastructure could be associated with the sources of infrastructure value as delineated in the previous section. For example, the purpose of applications support (Table 3, column 3) may be associated with the following sources of infrastructure value -- economies of scale and support of current strategy.

Table 3

Infrastructure Expenditures by an IT Infrastructure Purpose

(Thousands of Dollars) (source: Hoffman, 1994, p. 75)

Infrastructure Components	Budget Amounts	Percentage	Support Applications	System Security	Disaster Recovery	Support Flexibility	Support Standards
Operations							
Computers	$1,250	25%	$1,000	$125	$50	$75	
Telecomm.	500	10	375	25	50	25	25
Data Admin.	150	3	75	30	15	15	15
Help Desk	100	2	90				10
Total Operations	$2,000	40	$1,540	$180	$115	$115	$50
Application Development							
Maintenance	$1,000	20	1,000				
New Systems							
Marketing	450	9	270	45	45	45	45
Manufacturing	350	7	210	35	53	18	35
Human Res.	150	3	90	15	15	15	15
R& D	50	1	40	10			
Total new systems	$1,000	20	$610	$105	$113	$78	$95
Total application development	$2,000	40	$1,610	$105	$113	$78	$95
IT planning	250	5					
IT administration	500	10	350	50	50		50
Training	250	5	175				75
Total budget	$5,000	100	$3,675	$335	$277	$317	$395
% budget		100%	73%	7%	6%	6%	8%

Once this allocation process is complete, the management may be in a better to position to determine if adequate investments are undertaken to sustain the key sources of value to be derived from an IT infrastructure. For example, let us assume that a firm considers the provision of flexibility to accommodate changing business practices to be the key source of infrastructure value. The flexibility qualities of an IT infrastructure may be conceptualized as the compatibility of hardware resources, connectivity of networking resources, modularity of data and reuse of the application development tools and methodologies (Duncan, 1995). Such flexibility may enable the organization to quickly build new business applications, or to add new networking nodes to geographically dispersed business units to enable seamless transfer of critical information. If the review of the current infrastructure expenditures shows that only 6 percent of the total IT budget is spent for flexibility, the managers may either need to re-evaluate their expectations of infra- structure purpose or to prepare a justification for additional investments in infrastructure assets.

METHODS TO JUSTIFY ADDITIONAL INVESTMENTS IN AN IT INFRASTRUCTURE

Infrastructure investments, just like the public investments in the areas of flood control and public health, are characterized by large initial expenditures, payoff uncertainty, risk, and many intangible benefits allocated to a variety of stakeholders over a long period of time (Toraskar and Joglekar, 1993). Weill's (1992a) empirical observations of IT infrastructure use and management practices suggest that organizations vary in their approaches to justify additional infrastructure expenditures. The approaches range from traditional capital budgeting techniques to "gut feel" that infrastructure assets are critical to the long-term well-being of the organization.

Weill (1992a) suggests that some organizations used discounted cash flow techniques to justify their infrastructure expenditures. The expenditures that returned a positive discounted cash flow were approved while the ones with a negative cash flow were rejected. On the other hand, other organizations justified their infrastructure investments on the basis that such investments were required to achieve current or future strategies. Such justifications relied less on tangible, quantitative estimates of infrastructure value (e.g., reduced cost of selected IT services, fewer errors per line of code, etc.) and more on qualitative, intangible sources of value (e.g., future ability of an IS organization to build specific business applications, improved flexibility through reuse and sharing of resources).

The approach to justify IT infrastructure investments as well as the level of that investment and the expected benefits derived from such investment depend on the role IT infrastructure plays in the organization (Weill et al., 1993). For example, an organization that views IT infrastructure as a "utility" resource aimed to providing cost savings via economies of scale, may be better suited to use the net present value techniques to justify infrastructure investments since the inflows/ outflows of money and discounted rate could be reasonably estimated. On the other hand, the organization that views IT infrastructure as "enabling" resource aimed at providing flexibility to quickly respond to changing business needs, would be better off using other justification techniques since it may not be possible to quantify ahead of time the benefits to be derived from infrastructure investments.

Next, the methods to justify the investments in IT infrastructure resources will be presented for each of the three roles infrastructure plays in the organization - "utility," "dependent" and "enabling."

Investment Justification Method for the "Utility" Infrastructure

Organizations in which IT infrastructure plays a "utility" role consider infrastructure investments to be an administrative overhead expense and justify such expense on the basis of cost savings that result from economies of scale (Weill et al., 1993). Once the cost savings of the IT activities that result from the proposed infrastructure investments are identified, the management may use the net present value on discounted cash flow method to justify infrastructure investments.

Net Present Value Method (NPV)

Net Present Value is a traditional capital investment technique used by many organizations to justify investments in manufacturing and other types of capital equipment (Weston and Brigham, 1985). The NPV formula is shown in Figure 4. Managers may implement the NPV technique to justify infrastructure-related investments by deriving the present value of the net cash flows associated with such investments (e.g., cost savings that result from economies of scale), discounting such cash flows at the appropriate cost of capital, and subtracting from the resulting amount the cost of infrastructure resources. The NPV method is useful in the infrastructure justification decisions only if the inflows and outflows of money and the discount rate could be reasonably estimated.

Pros and Cons of the Net Present Value Method

The key advantage of using the NPV method to justify infrastructure investments is that this method provides quantitative estimates of the investment's value. Such estimates are appealing to managers who may be more comfortable with financial measures of capital performance than intangible, qualitative and "gut feel" measures. The relative ease of use is yet another advantage of this method.

The key disadvantage of using the NPV method to justify infrastructure investments is related to the accuracy of such method. Some elements of an IT infrastructure (e.g., IS staff expertise) are difficult to capitalize (Kriebel, 1993). Yet even if the investment costs are capitalized, the NPV estimates may still lack accuracy. The reasons is that infrastructure investments often pay off in ways that are very difficult to quantify. For example, quantifying improvements in software development productivity attributed to the proposed integrated computer aided software engineering (ICASE) tool is difficult at best. Some investment expenditures may yield a negative return on investment, yet be critical for the long-term competitive stance of an organization.

Investment Justification Method for the "Dependent" Infrastructure

Organizations in which IT infrastructure plays a "dependent" role consider infrastructure investments to be a business expense and tend to justify such expense on the basis of how well the infrastructure resources enable the current strategy of the firm (Weill et al., 1993). So the sources of value derived from a "dependent" infrastructure include, but are not limited to the following: expected benefits from applications that support current strategies, architectural standardization, and secure IT environment. While some of these benefits are more or less tangible (i.e., quality of systems as measured by errors per line of code), others are not (i.e., architectural standardization). A broadly-defined Cost-Benefit Analysis Methodology (Toraskar and Joglekar, 1993) may be applicable to justify the infrastructure investments that have both tangible and intangible benefits.

Figure 4

Net Present Value Formula

(source: Weston and Brigham, 1985, p. 339)

$$NPV = [\, CF_1/(1+k)^1 + CF_2/(1+k)^2 + \ldots CFn/(1+k)^n] - I = \sum_{t=1}^{n} CF_t/(1+k)^t - I.$$

where $CF_1 \ldots CFn$	*are net cash flows*
k	*is the appropriate discount rate (i.e., project's cost of capital)*
I	*is the initial cost of the project*
n	*is the project's expected life*

Cost-Benefit Analysis (CBA) Methodology

CBA methodology has been applied for many years to justify public investment decisions in areas such as flood control and national defense (Toraskar and Joglekar, 1993). Such investment decisions are complex, uncertain and translate into tangible as well as intangible benefits that accrue to many different stakeholders. Toraskar and Joglekar (1993) suggest that strategic IT investment decisions have very similar characteristics with the public investment decisions. Decisions to invest in the IT infrastructure that enable current strategy are also complex, involve tangible as well as intangible benefits, and affect many different stakeholders.

The CBA approach to assess cost/benefit of IT infrastructure investments is summarized in Figure 5. This approach includes five phases as recommended by Toraskar and Joglekar (1993):

- identification of changes associated with IT infrastructure investments (e.g., reduction in costs associated with providing a data administration IT service; improved integration of business applications)
- measurement of tangible changes (e.g., reduction of software errors per 100 lines of code) and comprehensive description of changes that can not easily be measured (e.g., improved transportability of applications across multiple platforms)
- explicit valuation of both tangible and intangible changesadjustment of explicit values for timing and uncertainty of their occurrence (e.g., discount rates and risk premiums)
- final assessment of infrastructure investment alternatives

Pros and Cons of the CBA Method

The key advantages of using the CBA method to justify IT investments are as follows (Toraskar and Joglekar, 1993):

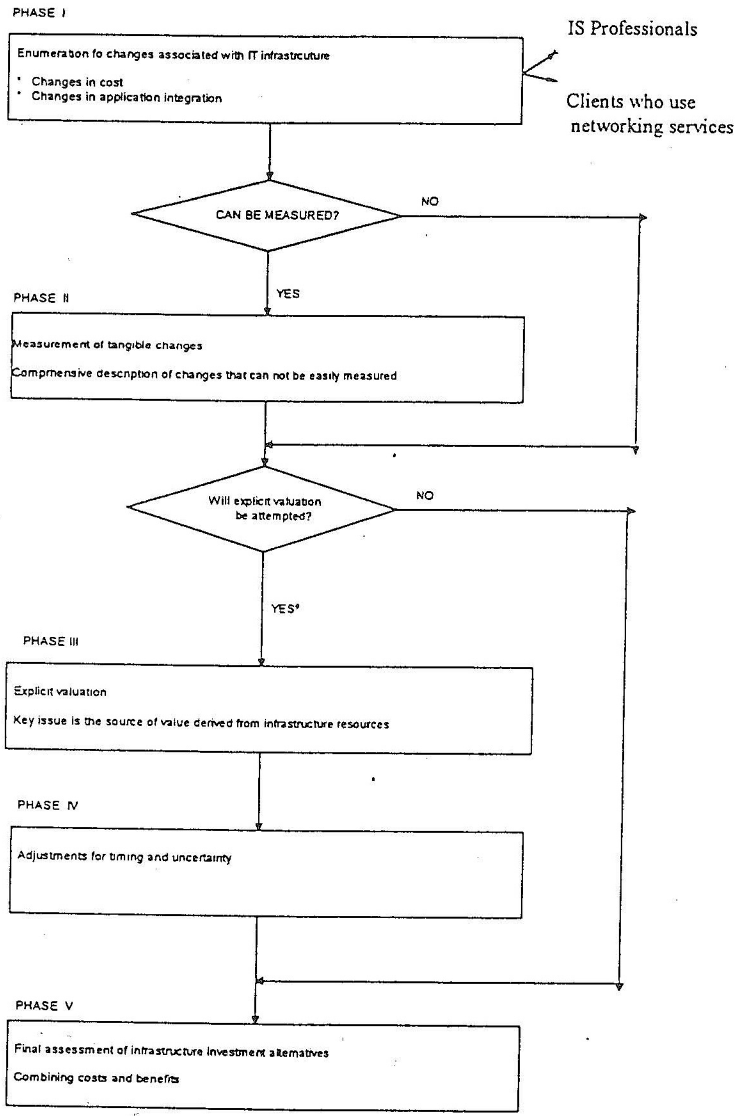
- the method measures intangible as well as tangible costs and benefits,
- the method takes into consideration the multi-dimensional nature of infrastructure investments; such investments affect many different stakeholder groups (e.g., IS professionals who provide IT-related services and clients who use business applications and networking services), and
- the method provides a comprehensive methodological base that includes tools, techniques and guidelines on when to use various tools and techniques.

The CBA method, however, is not without faults. The IT investment literature criticizes this method for its emphasis on quantification of intangibles, disregard for the nature of strategic IT investments that are risky and uncertain, ignorance of non-economic issues (i.e., quality of life), focus on efficiency not effectiveness, and a bias towards investments that have a short-term payoff (Toraskar and Joglekar, 1993). Some of the above limitations may be avoided by broadening the tool kit of alternative techniques. Moreover, being cognizant of the above problems is the first step towards avoiding some of them as the IS managers attempt to apply the CBA method to justify investments into "dependent" IT infrastructure.

Investment Justification Method for the "Enabling" Infrastructure

Organizations in which IT infrastructure plays an "enabling" role consider infrastructure expenditures to be a business investment (Weill et al., 1993). Furthermore, they justify such an

Figure 5
Flowchart of the Cost-Benefit Analysis Methodology



investment on the basis of how well it enables the current and future flexibility to achieve the strategic aims of the firm. Infrastructure investments today may often be necessary for future investments in transactional, informational and strategic applications (Weill, 1992b). Thus, investing into "enabling" infrastructure resources is like investing into organizational capabilities that may be required in the future to sustain or gain competitive advantage. But how could the firm justify investments in an IT infrastructure that provides an option to invest in future applications that in turn would provide value to the organization in the long run? Clearly, there is a need to value such an option.

Kambil et al. (1993) propose a framework based on the financial options theory to value the IT investments "real option", that is an opportunity to implement strategies for future growth. This framework could be applied to the IT infrastructure context. The framework suggests that the value of an infrastructure investment option would be in enabling future value-adding IT activities to take place.

What is a "real option" and how could it be valued? Kambil et al. (1993) define a "real option" as follows:

> "... implicit contracts to exercise new information systems based business strategies during the life-time of a specific investment, or to expand or adapt existing projects and strategies to changing environmental contingencies" (p. 165).

The formula to estimate the value of a "real option" provided by an IT infrastructure investment is shown in Appendix A. To illustrate the above framework an example of a hypothetical company faced with the need to justify an IT infrastructure investment will be presented. The company, XYZ Unlimited, has yearly revenues of approximately $10 million and specializes in manufacturing of office supplies. The Chief Executive Officer of the company recognizes the need to reduce the time it takes for his organization to respond to market needs, and to shorten new product development cycle. He wants the development of new business systems that would enable his strategy. Thus, there is an increasing pressure on XYZ's IS organization to develop future business applications that keep pace with changing organizational needs.

The company's Chief Information Officer (CIO), in reviewing the way business applications are developed, finds that the traditional software development process employed by his organization often leads to budget/time schedule overruns and failed systems. Furthermore, he believes that an integrated computer-aided software engineering environment (i.e., ICASE tools and methodologies) could improve the timeliness of the future systems development effort, and the effectiveness as well as the flexibility of the newly developed software. Thus, the CIO is faced with the need to justify the investment in the IT infrastructure (i.e., ICASE tool, methodology, training) that would enable a more effective development of the future business applications.

The estimate to acquire an option on future business applications enabled by the investments in the ICASE environment will be derived following the steps suggested by Kambil et al. (1993). These steps are detailed in Appendix B. The estimates derived in Appendix B suggest that the value of an option ($113,251) exceeds the present value of the initial investment Ip = $100,000. Since the infrastructure investment appears to add positive value to the firm, the CIO would now be in a better position to justify the investment in the ICASE environment.

Pros and Cons of the "Real Option" Method

The key advantage of using the "real option" framework to justify future infrastructure investments is that such a framework provides a systematic approach to estimate and quantify the value of yet uncertain future projects made possible by the initial investment in an IT infrastructure. Moreover, the "real option" approach enables the organization to more effectively align its business, IT and financial strategies aimed at increasing the overall value for the organization (Kambil et al., 1993).

The downside of applying the "real option" method to justify infrastructure investments is that this method appears to be quite complex. Moreover, the effective use of this method requires fairly robust estimates of the expected cash flows and the cost of exercising the "real option" (Kambil et al., 1993). It may be difficult to appropriately estimate the cash flows from infrastructure investments since IT infrastructure enables many future projects and provides value to many different stakeholders.

Summary

This section has presented three different methods to justify future investments in IT infrastructure -- net present value, cost-benefit analysis and the "real option." While each of the three justification methods has its advantages and limitations, they nevertheless are viable approaches to estimate the tangible as well as the intangible nature of infrastructure expenditures.

CONCLUSION

Investments in IT infrastructure resources are usually large, uncertain, and risky. Moreover, the benefits derived from infrastructure are indirect, largely qualitative, and accrue to many different stakeholders. Thus, it is difficult to tie infrastructure investments directly to organizational performance. Consequently, the difficulty with ascertaining the infrastructure value makes it even more difficult for the managers to justify additional infrastructure investments. The three-phased approach to assess the economic viability of infrastructure resources presented in this paper is aimed at helping IS and general managers make more informed decisions as to their infrastructure investments. The proposed approach consists of the three interdependent phases. The first phase deals with identifying the sources of infrastructure value. The second phase deals with assessing the cost and value of the firm's installed infrastructure resources. The third phase deals with justifying additional investments in an IT infrastructure.

The key managerial challenge associated with developing and sustaining a robust foundation for the firm's business activities is assessing infrastructure payoff. The application of the payoff assessment approach proposed in this paper is one of the first step towards addressing this challenge.

APPENDIX A

Formula to Estimate the Value of a "Real Option" Provided by an IT Infrastructure Investment

$$C = \{ Cu\, [(r-d) / (u-d)] + Cd\, [(u-r) / (u-d)] \} / r$$

where:

$Cu = max[\ 0,\ u*S - K\ ]$	present value of the call option based on the optimistic scenario (note: optimistic and pessimistic scenarios are derived based on he identification of project risks)
$Cd = max[\ 0,\ d*S - K\ ]$	present value of the call option based on the pessimistic scenario
S	is a "twin security" with the same risk characteristics of the original project (i.e., investment in IT infrastructure); has a log normal return distribution; fluctuates in value during a specific period (e.g., one year) same as the original project
$u*S$	increase in value of the real project by the "upside" factor u
$d*S$	decrease in value of the real project by the "downside" factor d
u and d	changes in value of the "twin security" S expressed as multiples
K	exercise price of the real option (i.e., the cost of building a business application on top of the existing infrastructure a year from now)
r	rate of return based on the weighted average cost of capital

(source: Kambil et al., 1993)

APPENDIX B

Steps to Estimate the Value of Acquiring an Option on Future Business Applications Enabled by the Investments in the Integrated Computer Aided Software Engineering (ICASE) Environment

Step 1 Derive the traditional net present value estimate for the project of developing future business applications using the ICASE environment

- **Step 1a** Estimate Project Costs
  - the ICASE tool, methodology, training (i.e., IT infrastructure) would cost $100,000; application programming for the new business systems would cost $120,000; I_0 = $220K
- **Step 1b** Identify Project Risk
  - the key organizational risk associated with this project is the acceptance of the new ICASE environment by the software developers. Empirical literature suggests that the implementation of CASE tools is often met by the software developers with resistance and even sabotage (Orlikowski, 1989).
- **Step 1c** Estimate Cash Flows Under Different Scenarios
  - optimistic scenario is that the ICASE environment will be successfully accepted by the software developers of the XYZ Unlimited organization (40 percent probability); estimated perpetual annuity in savings from this project are $80,000; these savings will be realized beginning one year from the initial investment.
  - pessimistic scenario is that the ICASE environment will not be successfully accepted by the software developers (60 percent probability); estimated perpetual annuity in savings will be only $10,000; these savings will be realized beginning one and a half year from the initial investment
- **Step 1d** Estimate the Cost of Capital

- the cost of capital is assumed to be 20 percent as suggested by Kambil et al. (1993)

- **Step 1e** Estimate Traditional Net Present Value

  - Formula for the present value of the perpetual annuity that begins a year from now is PV = Annual cash flow / r (Kambil et al., 1993, p. 178)
  - Formula for the expected present value of the project is as follows (Kambil et al., 1993, p. 169)

    E(PV) = (PV optimistic) * optimistic probability +
    (PV pessimistic) * pessimistic probability

    Formula for the net Present Value of the project is:
    NPV = E(PV) - I_o

  - The following calculations are based on the above formulas:

    PV (optimistic scenario) = \$ 80,000 / 20% = \$400,000
    PV (pessimistic scenario) = \$ 10,000 / 20% = \$

    E(PV) = \$400,000 * 0.4 + \$50,000 * 0.6 = \$ 190,000
    NPV = E(PV) - Io = \$190,000 - \$220,000 = - \$ 30,000

- **Step 1f** Conclusions from the NPV Analysis

  - The proposed investment has a negative net present value. Based on this estimate, the project should not be authorized. The next step, however, is to estimate the value of acquiring an option on future business applications by investing in IT infrastructure. If the value of this option exceeds the present value of the initial investment, the CIO may be in a better position to justify infrastructure investment.

Step 2 Estimation of Project Cost

- Initial project investments (i.e., infrastructure investments) is \$100K; thus Ip = 100K

- The cost to expand the project a year from now (i.e., building new applications, implementation, training, conversion, etc.) is $120K

Step 3 Defining the Option

- Investing in the ICASE environment (i.e., IT infrastructure) may be compared to obtaining a "single period call option" on the new business systems development project

- Cu = max[0, u*S - K] = max[0, 480K - 120K] = $360K
  Cd = max[0, d*S - K] = max[0, 60K - 120K] = $0
  u*S = (1 + 1.2) * 400,000 = $480K
  d*S = (1 + 1.2) * 50,000 = $60K
  u = 2.53; d = .32; r = 1.05 (risk-free rate of return)

Step 4 Estimating the Option Value

- C = { 360K[(1.05 - .32) / (2.53 - .32)] + 0K [(2.53 - 1.05) / (2.53 - .32)]} / 1.05 = $113,251

Step 5 Investment Decision

REFERENCES

Boynton, A.C. & Zmud, R.W. (1987). "Information Technology Planning in the 1990's: Directions for Practice and Research," ***MIS Quarterly***, 11(1), 100-115.

Brynjolfsson, E. (1993). "The Productivity Paradox of Information Technology," ***Communications of the ACM***, 36(12), 66-77.

Brynjolfsson, E. & Hitt, L. (1993). "Is Information Systems Spending Productive? New Evidence and New Results." In DeGross, J.I. , Bostrom, R. P. & Robey. D. (Eds.). Pp. 47-64. *Proceedings of the Fourteenth International Conference on Information Systems*, Orlando, Florida.

Davenport, T. & Linder, J. (1994). "Information Technology Infrastructure: The New Competitive Weapon?" *Working Paper*, Ernrst & Young, 1-26.

Duncan, N. B. (1995). "Capturing Flexibility of Information Technology Infrastructure: A Study of Resource Characteristics and their Measure." ***Journal of Management Information Systems***, 12(2), 37-57.

Hoffman, G.M. (1994). ***Technology Payoff: How to Profit with Empowered Workers in the Information Age***, Burr Ridge: Irwin Professional Publishing.

Kambil, A., Henderson, J. & Mohsenzadeh, H. (1993). "Strategic Management of Information Technology Investments: An Options Perspective." In Banker, R.D., Kauffman, R. J. & Mahmood, M. A. (Eds.). ***Strategic Information Technology Management: Perspectives on Organizational Growth and Competitive Advantage.*** Pp. 161-178, Harrisburg: Idea Group Publishing.

Kriebel, C.H. (1993). "Formal Models in Research on IT Investment Evaluation." In Banker, R.D., Kauffman, R. J. & Mahmood, M. A. (Eds.). ***Strategic Information Technology Management: Perspectives on Organizational Growth and Competitive Advantage.*** Pp. 25-31, Harrisburg: Idea Group Publishing.

Markus, M.L. & Soh, C. (1993). "Banking on Information Technology: Converting IT Spending into Firm Performance." In Banker, R.D., Kauffman, R. J.& Mahmood, M. A. (Eds.). ***Strategic Information Technology Management: Perspectives on Organizational Growth and Competitive Advantage.*** Pp. 375-403, Harrisburg: Idea Group Publishing.

McKay, D.T. & Brockway, D.W. (1989). "Building I/T Infrastructure for the 1990s," ***Stage by Stage***, 9(3), 1-11.

Niederman, F., Brancheau, J.C. & Wetherbe, J.C. (1991). "Information Systems Management Issues for the 1990s," ***MIS Quarterly***, 15(4), 475-495.

Orlikowksi, W.J. (1989). "Division Among the Ranks: The Social Implications of Case Tools For Systems Developers." In DeGross, J.I., Henderson, J. & Konsynski, B. (Eds.). Pp. 199-210, *Proceedings of theTenth International Conference on Information Systems*, Boston, Massachusetts.

Rockart, J.F. (1992). "The Line Takes the Leadership - IS Management in a Wired Society," ***Sloan Management Review***, 33(4), 47-54.

Soh, C. and Markus, M. L. (1995). "How IT Creates Business Value: A Process Theory Synthesis." In DeGross, J. I., Ariav, G., Beath, C., Hoyer, R. & Kemerer, C. (Eds.). *Proceedings of the Sixteenth International Conference on Information Systems*, Pp. 29-41, Amsterdam, The Netherlands.

Toraskar, K. & Joglekar, P. (1993). "Applying Cost Benefit Analysis Methodology for Information Technology Investment Decisions." In Banker, R.D., Kauffman, R. J.& Mahmood, M. A. (Eds.). ***Strategic Information Technology Management: Perspectives on Organizational Growth and Competitive Advantage.*** Pp. 119-142, Harrisburg: Idea Group Publishing.

Weill, P., Broadbent, M., Butler, C. & Soh, C. (1995). "An Exploration of Firm-Wide Information Technology Infrastructure Investment and Services." In DeGross, J. I., Ariav, G., Beath, C., Hoyer, R. & Kemerer, C. (Eds.). *Proceedings of the Sixteenth International Conference on Information Systems*, Amsterdam, The Netherlands.

Weill, P., Broadbent, M. & St. Clair, D. (1993). "IT Value and the Role of IT Infrastructure Investments," *Working Paper*, 1-26.

Weill, P. (1992a). "The Role and Value of Information Technology Infrastructure: Some Empirical Observations." *Working Paper, #240*, Center for Information Systems Research, Sloan School of Management, Massachusetts Institute of Technology, 1-33.

Weill, P. (1992b). "The Relationship Between Investment in Information Technology and Firm Performance: A Study of the Valve Manufacturing Sector," ***Information Systems Research***, 3(4), 307-331.

Weston, J.F. & Brigham, E. F. (1985). ***Essentials of Management Finance***, Seventh Edition, New York: CBS College Publishing.

Wilson, D. D. (1993). "Assessing the Impact of Information Technology on Organizational Performance." In Banker, R.D., Kauffman, R. J.& Mahmood, M. A. (Eds.). Pp. 471-514, ***Strategic Information Technology Management: Perspectives on Organizational Growth and Competitive Advantage.*** Harrisburg: Idea Group Publishing.