Assessing the Organizational Impact of IT Infrastructure Capabilities

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Abstract

It has been strongly argued that information technology (IT) infrastructure has a strategic impact on an organization. However, no empirical examination of this relationship has been performed. In this paper, based on a survey of 236 firms, the organizational impact of IT infrastructure is assessed using a research model incorporating both direct and indirect impacts. Our results show that, although there was little direct impact, IT infrastructure had a significant indirect effect on organizational performance through its impacts on IS functional effectiveness and business process effectiveness.

The results suggest that, in and of themselves, IT infrastructure capabilities have little business value. Investments in IT infrastructure will be seriously undervalued if they are assessed only in terms of its direct link to organizational performance. IT infrastructure is of strategic importance to an organization because it either enables or inhibits IT applications and business processes. It is the manner in which IT infrastructure investments are applied to enhancing IS functional performance and to improving business processes that is key to realizing their business value.

Assessing the Organizational Impact of IT Infrastructure Capabilities

Introduction

IT infrastructure issues are affecting all businesses (Leclaire, Cooper and Gorrio, 2000). Because IT infrastructure is often intertwined with organizational structure and business processes, it can be either an enabler or a barrier for planning and implementing new competitive strategies and organizational changes (Broadbent, Weill and St Clair, 1999; Davidson and Movizzo, 1996). This becomes more critical as the new electronic business is forcing companies to make fundamental changes to their business strategies and processes, and do it fast. In addition, technologies (both hardware and software) are advancing at the speed we have never experienced before, with shorter life cycle and faster performance improvement. Companies must continuously upgrade and renew their IT systems. However, IT and business changes can not be implemented successfully without an IT infrastructure that supports the changes.

It is difficult to change IT infrastructure in a short period time because it involves large investments and evolves over a long period of time (Xia and King, 1999). IT infrastructure investments have grown rapidly from 4.08% of GDP in 1996 to 4.53% in 1997 (*Business Week*, 1999) until they now represent more than 50% of total business investments. Such investments account for more than 58 percent of total IT budgets and about four percent of firm revenues, and they have increased at about 11 percent annually (Weill and Broadbent, 1998). As IT systems and application packages become increasingly diversified and multi-media based, a key challenge IT managers face today is maintaining an IT infrastructure that is capable of supporting not only what the organization is doing but also the changing business needs. Very often, IT application projects failed or were significantly delayed because the needed

infrastructure was not in place. This is particularly the case in companies' strive to deploy electronic business applications. Many organizations found that IT infrastructure today is more often an inhibitor of change than an enabler (Broadbent et al., 1999). As a result, IT infrastructure becomes an increasingly important factor that affects organization competitiveness (Weill and Broadbent, 1998). The importance of this issue is evidenced by a survey of top information systems (IS) executives who ranked building a responsive IT infrastructure as the most important IS management issue (Brancheau, Janz and Wetherbe, 1996).

Despite the widespread acceptance of the strategic importance of IT infrastructure, the management of IT infrastructure remains poorly understood in industry (Weill and Broadbent, 1998). Because infrastructure is so fundamental to all businesses and business processes that its role and importance are too often ignored. IT infrastructure does not receive adequate attention at the time of decision making for IT investments, nor does it receive adequate recognition in the planning and implementation of IT systems and applications. The funding of infrastructure improvements is the hardest to sell to senior executives because it is difficult to assess and justify the business value of large infrastructure investment. As a result, many IT application projects are planned and implemented without a careful assessment of the need for infrastructure changes. Determining whether and under what conditions IT infrastructure adds value to firms is an important management question.

Research on IT infrastructure is still in its early theory development stage. Most publications are conceptual and anecdotal in nature (e.g., Broadbent and Weill, 1997; Earl, 1989; Grossman and Paker, 1989; Keen, 1991; Mata, Furest and Barney, 1995; McKay and Brockway, 1989; Weill, 1993; Weill and Broadbent, 1998). A few studies have examined the characteristics of IT infrastructure (Broadbent, Weill, O'Brien and Neo, 1996; Broadbent et al., 1999; Duncan,

1995). To the best of our knowledge, no research has empirically studied the relationship between IT infrastructure and organizational performance. A general limitation of this literature is the lack of theories that guides systematic investigation of the impact of IT infrastructure. Without a theoretical foundation and a cumulative body of empirical research, our understanding of IT infrastructure and its organizational impact will remain too anecdotal and general to provide managers with useful insights and recommendations for evaluating and managing their IT infrastructure.

The purpose of this study is to determine whether and how IT infrastructure affects organizational performance. A research model is developed that proposes both a direct effect of IT infrastructure on organizational performance and an indirect effect mediated by the effects of IT infrastructure on IS functional effectiveness and business process. The paper is organized as follows. In the next section, the concept and characteristics of IT infrastructure are defined. The literature on the business value of IT is then reviewed to setup the conceptual basis for the research model tested in this study. The forth section develops the research model and hypotheses. In the research methods section, sample, data collection procedures and measures of the variables are described. The sixth section reports the testing results of the research model and hypotheses. The paper concludes with a discussion of the implications of the study.

Background

In this section, we review the literature on IT infrastructure and discuss the concept and characteristics of IT infrastructure.

The concept of IT infrastructure

According to the American Heritage College Dictionary, infrastructure refers to (1) an underlying base of foundation, especially for an organization or a system; and (2) the basic

facilities, services and installations needed for the functioning of a community or society, such as transportation and communications systems. Thus, an infrastructure is the foundation or base upon which something else "runs" or "operates." In other words, it is the foundation or base without which something else can not run or operate.

There is general consistency and agreement among researchers on the definition of IT infrastructure. McKay and Brockway (1989) define IT infrastructure as the enabling foundation of shared information technology capabilities upon which business depends. They view IT infrastructure as the shared portion of the IT architecture. Earl (1989) defines IT infrastructure as the technological foundation of computer, communications, data and basic systems. He views IT infrastructure as the technology framework that guides the organization in satisfying business and management needs. Duncan (1995) refers to IT infrastructure as the set of IT resources that make feasible both innovations and the continuous improvement of IT systems. Broadbent et al. (1996) describe IT infrastructure as the base foundation of budgeted-for IT capability (both technical and human), shared throughout the firm in the form of reliable services, and usually managed by the IS group.

Thus, IT infrastructure is generally considered to be the foundation of shared IT capabilities that enable the development of IT applications and the support of business processes. In this study, *IT infrastructure is defined as a set of IT resources and organizational capabilities that are shared across the organization and that provide the foundation on which IT applications are developed and business processes are supported.*

Characteristics of IT infrastructure

Star and Ruhleder (1996) characterize an infrastructure in terms of seven dimensions: embeddedness, transparency, reach or scope, links with conventions of practice, embodiment of standards, built on an installed base, and becomes visible upon breakdown.

In addition to these generic characteristics of infrastructure, some specific characteristics have been suggested. Of particular importance are those characteristics that differentiate IT infrastructure from conventional applications projects. Grossman and Packer (1989) identify five such characteristics: champion/driver, purpose, scope, design requirements, and management processes.

The champion, or driver, for IT infrastructure is usually the senior IT executive, while for a business application project the champion is often the business manager. The purpose of a business application project is to deliver business functionality, while the purpose of IT infrastructure is to provide a platform for future business applications. The scope of a business system is relatively narrow, usually supporting one business process, product or function, whereas the scope of IT infrastructure is much broader, crossing most functions and products. The design requirements for business systems must fit within the existing IT infrastructure, while IT infrastructure projects have the objective of redefining and removing restrictions from the firm's IT capability. In terms of management processes, for business application projects the objective is to eliminate uncertainty as part of the specification process. In contrast, IT infrastructure projects must cope with the uncertainty of future needs in terms of both IT applications development and business changes. IT infrastructure investments require decisions as to how much flexibility, and thus tolerance of uncertainty, should be built into the infrastructure as well as concerning the specific mechanisms for doing so.

Models of IT infrastructure

McKay and Brockway (1989) provide a planning model that outlines the relationships between business planning and technology infrastructure planning. The portion of their model that describes the three-layers of IT infrastructure was later adapted and further elaborated by Weill (1993). Based on their work, Figure 1 illustrates these basic elements of IT infrastructure. IT infrastructure is shown as the foundation that support specific IT applications which in turn enable the functioning of business processes.

Insert Figure 1 about here

At the base of this figure are the shared technological components that constitute the basic building blocks of infrastructure hardware and software. These components include the hardware, operating software, communications, other equipment and support required to enable business applications (Earl, 1989; Turnbull, 1991). These technological components are readily available in the marketplace (Weill, 1993) and thus, in and of themselves, provide no unique value, although most organizations spend large portions of their resources evaluating the merits of, and procuring, these IT components.

The "top" layer of the figure is a set of shared IT services such as universal file access, electronic data interchanged (EDI) or a full-service network. The IT components are combined into shared IT services that support IT applications and business process capabilities. These shared IT services link IT components to business capabilities to create a broader base of IT functionality and value. Broadbent et al. (1996) and Weill and Broadbent (1998) define this set of shared IT services as the range of IT infrastructure.

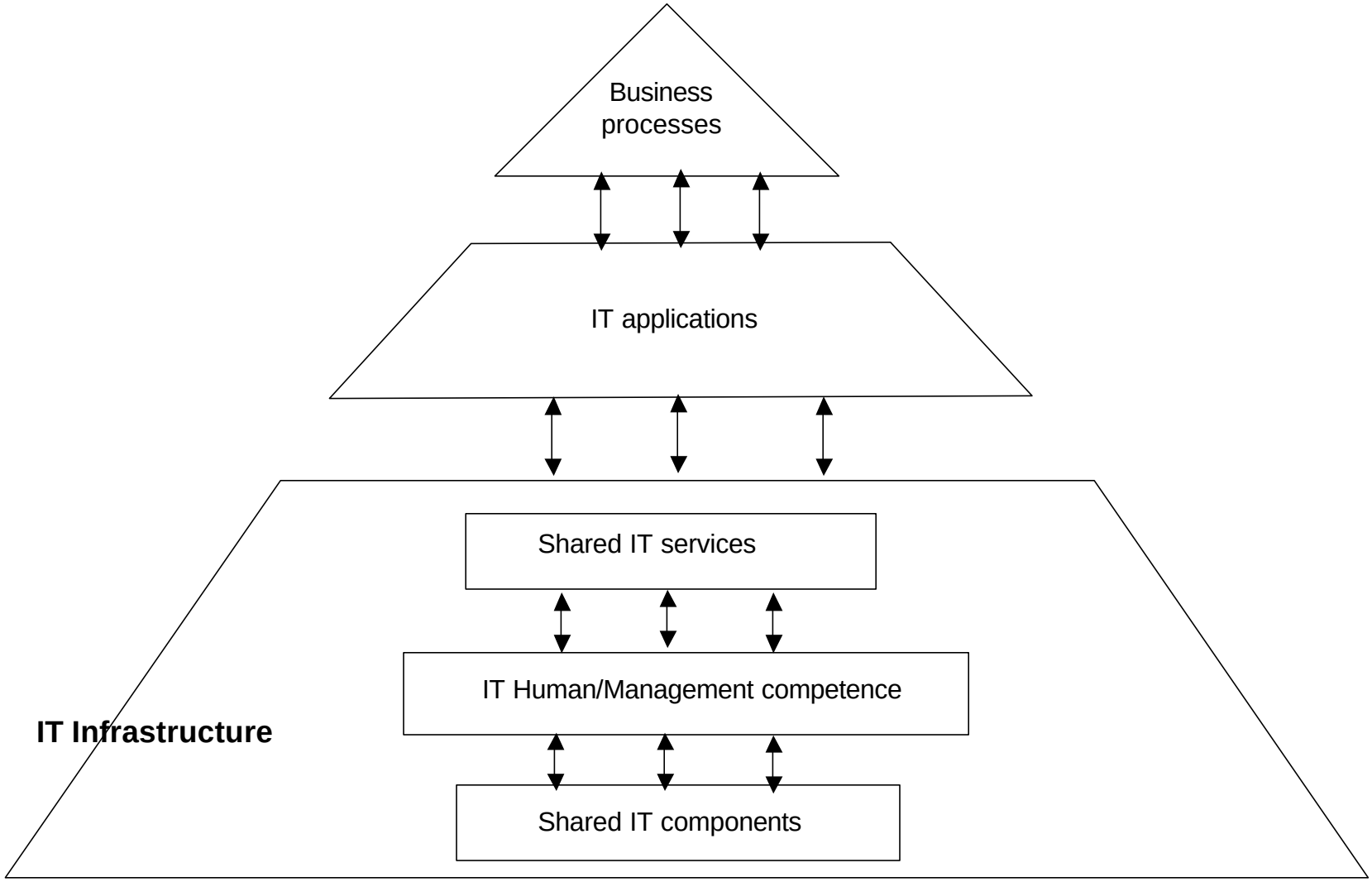

Figure 1. Key Components of IT Infrastructure (Adapted from McKay and Broackway, 1989)

In Figure 1, the middle layer of IT infrastructure is the human and organizational capabilities that are needed to effectively utilize, leverage and bind all the IT components into robust and functional IT services. McKay and Brockway (1989) refer to those human and organizational capabilities as "mortar." Duncan (1995) refers to them as infrastructure planning and management factors. This layer represents capabilities that combine and deploy the technological components into a shared set of capabilities or services that are fundamental to the operation of the business. The elements of this layer allow other "direct purpose" uses of technology to be feasible, and allow the successful implementation of the IT architecture.

IT human resources represent not only the technical skills but also the managerial and organizational skills of IT professionals to innovate and support critical business processes. IT planning and management practices produce the architectures, plans, standards, policies and rules that govern the development of the technological components of IT infrastructure across the organization.

Empirical studies of IT infrastructure

In the empirical literature, Peter Weill and his colleagues have done extensive field studies on the characteristics of IT infrastructure (Weill, 1993; Broadbent et al., 1996; Weill and Broadbent, 1998; Broadbent et al., 1999). They have examined two characteristics of IT infrastructure: reach and range. Reach refers to the extent to which the various IT components and business functions are connected through IT infrastructure (Keen, 1991). Range refers to the extent to which key IT services are provided by the corporate IS function as part of infrastructure services (Broadbent et al., 1996; Weill and Broadbent, 1998). Their research has focused mainly on the independent variables that influence IT infrastructure's reach and range. The results of

their studies suggest that more extensive of IT infrastructure reach and range were found in firms with (1) rapid product change, (2) demands for synergies across business units, (3) needs for integration of information and IT in the planning process, and (4) practices of tracking the implementation of long term strategy.

Duncan (1995) reported another study on IT infrastructure. Using a survey of 82 organizations in the life/health insurance industry, Duncan (1995) studied the relationships among IT infrastructure, perceived roles of IT investment, outsourcing, and responsiveness of IT function. Due to the inadequacy of her measures (e.g., measures on the responsiveness of IT function and some measures on IT infrastructure components), she was unable to test the complete model; instead, a partial model was tested. She reported that certain dimensions of IT infrastructure such as modularity, compatibility, and connectivity were determined by (1) management attitudes toward the value of IT resources and (2) the support of organizational structures. She also found that outsourcing key data processing systems was associated with a decrease in flexibility of those resources.

To the best of our knowledge, no research has empirically examined the relationship between IT infrastructure and organizational performance. Two factors may explain this lack of research . One explanation is that the recognition of the importance and significance of IT infrastructure is a relatively recent phenomenon. "Building a responsive IT infrastructure," first appeared, and was ranked sixth as an issue of importance, in the 1991 annual survey of members of the Society for Information Management (SIM) (Niederman, Brancheau and Wetherbe, 1991). It was then ranked as the most important IS management issue in the 1996 survey (Brancheau et al., 1996). This suggest that only in the recent past that managers have started to devote special attention to issues related to IT infrastructure.

The second reason is undoubtedly that it is much more difficult to measure the attributes of IT infrastructure than it is to measure those of specific IT applications or systems (Markus and Soh, 1993). The lack of appropriate approaches and instruments for measuring IT infrastructure may have contributed to the scant efforts to empirically study the characteristics and organizational roles of IT infrastructure.

Evaluating the Business Value of IT

Since the organizational impact of IT infrastructure has not been empirically investigated, the literature on the business value of IT investment is reviewed to develop a conceptual understanding of the relationship between IT infrastructure and organizational performance.

Assessing the business value and organizational impact of IT investment has long been an important issue for both researchers and practitioners. In general, empirical studies in this area can be grouped into two research streams. The first research stream, primarily goal-oriented, consists of studies that attempt to establish a direct link between IT investment and measures of organizational performance. The second research stream, mainly process-oriented, consists of studies that attempt to establish an indirect link between IT investment and organizational performance through some intermediate process measures that are directly affected by IT investment and use.

"Goal-oriented" research on the direct link between IT investment and performance

Research that studies the direct link between IT investment and performance can be further divided into two groups. The first group of studies focuses on the macro impact of IT at either the economy or the industry level. The second group examines the impact of IT at the firm level.

At the economy and industry levels, researchers have attempted to link IT spending with outcome measures of productivity. In a widely cited study of IT impact on the productivity of information and production workers, Roach (1987) found that information worker productivity had either declined in some sectors or not kept pace with production worker productivity in the manufacturing sector. Loveman (1988) studied the manufacturing sector for the period from 1978 to 1984 and found no evidence that IT spending positively impacted productivity. Similarly, other studies reported either a negative relationship (e.g., Berndt and Morrison, 1992; Roach, 1991) or no relationship (e.g., Baily and Chakrabarti, 1988; Morrison and Berndt, 1990; Osterman 1986) between IT investment and productivity.

At the firm level, researchers have focused on the relationship between IT investment and measures of firm performance such as ROI and market share. In one of the earliest studies in this area, Cron and Sobol (1983) examined the relationship between three levels of computer utilization and four measures of firm profitability. They found that on average, the impact of IT was not significant, but that it seemed to be associated with both very high and very low performers. Bender (1986), Harris and Katz (1988, 1991), Strassman (1990) and Weill (1992) also found similar bi-model relationship. A number of studies (e.g., Krafcik, 1988; Oman and Ayers, 1988; Pentland, 1989; Stabell and Forsund, 1983; Turner, 1985) reported no significant relationship between IT firm performance. More recent studies (e.g., Alpar and Kim, 1990; Banker and Kauffman, 1988; Brynjolfsson, 1996; Brynjolfsson and Hitt, 1993; Floyd and Wooldridge, 1990; Hitt and Brynjolfsson, 1994; Lichtenberg, 1993; Tam, 1998), have reported significant positive relationship between IT and firm performance.

In summary, empirical studies have failed to demonstrate a consistent direct link between IT investment and performance. The overall findings of this research stream have been

contradictory, ranging from a significant negative, to no significant relationship, to a bi-modal relationship, to a significant positive relationship. Frustrated with the diappointing observation that there was no or even negative relationship between IT spending and productivity, Roach (1988, 1989) coined the term "IT productivity paradox." Loveman (1988) even concluded that "the marginal dollar would best have been spent on non-IT input into production, such as non-IT capital." Solow (1987) lamented that "you can see the computer age everywhere but in the productivity statistics."

Mixed empirical results call for alternative theories and research approaches. Soh and Markus (1995) contend that a productive research approach would be moving from the question of whether IT creates value to how, when and why benefits occur or fail to do so. Among the most compelling and widely accepted alternative approaches is one called the "process-oriented" approach. This approach points out problems related to the measurement and tracing of IT impacts using a single productivity measure. It argues that enterprise level impacts of IT can be measured only through a "web of intermediate level contributions" and calls for more detailed investigation of how IT actually creates impacts close to the level of implementation (Banker and Kauffman, 1988; Barua, Kriebel and Mukhopadhyay, 1995; Crowston and Treacy, 1986; Kauffman and Weill, 1989; Kauffman and Kriebel, 1988a, 1988b; Kriebel, 1989; Mukhopadhyay and Cooper, 1992; Weill, 1992).

"Process-oriented" research on the indirect link between IT investment and performance

As discussed above, most studies that attempt to establish a direct link between IT investment and business value have used traditional measures of productivity. The traditional measures of productivity, while important, are not necessarily appropriate measures of IT business value and impact. IT investment and use affect various aspects of the organization and

produce a broad spectrum of intermediate benefits such as improved production output, quality, customer service and supplier relationships (Barua et al., 1995; Brynjolfsson and Hitt, 1996; Hitt and Brynjofsson, 1996). Traditional measures of productivity fail to capture these intermediate benefits and thus underestimate the value of IT.

Related to this measurement issue is the problem of modeling a direct link between IT investment and organizational performance. The direct linkage modeling approach, on which the paradox rests, is based on the assumption that different firms are equally efficient and effective in converting IT investments into organization-level output. In reality, not all organizations are able to convert their IT dollars into IT assets with the same efficiency (Weill, 1992). Markus and Soh (1993) argue that IT investment or spending does not necessarily directly lead to improved organizational performance because some of the investment may be wasted due to poor IT management, ineffective system design and organizational problems. The direct linkage approach omits the intermediate processes through which IT investment is converted into organization-level output.

Recognizing these measurement and modeling problems, researchers have proposed the use of multi-faceted measures of IT impact (Sethi and King, 1994; Mooney, Gurbaxani and Kraemer, 1995). Several researchers have proposed models that link IT investment to organizational performance through some intermediate processes. These process-oriented models trace the path or chain of activities IT investment takes on the way to reaching firm-level performance.

Markus and Soh (1993) propose a model involving two sequential processes. The first process explains how IT investment is converted into appropriate IT assets including IT infrastructure and a portfolio of applications. The second process explains how IT assets do or

do not yield improved organizational performance. Soh and Markus (1995) propose a modified version of the model which includes three processes. The first process, "the IT conversion process," translates IT expenditures into IT assets. The second process, "the IT use process," links IT assets with IT impacts on business processes. The third process, "the competitive process," links IT impacts with organizational performance.

Beath, Goodhue and Ross (1994) propose a similar model involving two processes: the first connects IT assets with IT-based business processes and the second connects IT-based processes with business value. They propose that IT assets improve organizational performance by affecting three intermediate processes: cycle time of application systems development, productivity of operations, and strategic alignment of planning.

Sambamurthy and Zmud (1994) propose an "IT impact" model that consists of three subprocesses. The first process connects organizational input factors to IT management roles and processes, the second connects IT management roles and processes to impacts on IT-based business processes, and the third connects impacts on IT-based business processes to business value.

Mooney et al. (1995) argue that firms derive business value from IT through its impacts on intermediate business processes. The intermediate processes include the operational processes that comprise a firm's value chain and the management processes of information processing, control, coordination and communication. The potential business value of IT increases as IT continues to permeate and penetrate the organization, impacting an increasing number of processes at a deeper level.

Four empirical studies have examined the impact of investments in EDI applications on measures of intermediate process outcomes and measures of firm performance. Kekre and

Mukhopadhyay (1992) reported a field study at LTV Steel investigating the business value of the company's EDI linkages with outside processors on its process outcomes. They found that, compared to the old manual mode of information exchange, EDI transactions had more favorable effects on quality and inventory measures. Srinivasan, Kekre and Mukhopadhyay (1994) reported a field study that investigated the relationship through EDI between an automobile manufacturing company and its first-tier suppliers. They found that the use of integrated EDI to share schedule information lowered the level of shipping discrepancies.

Barua et al. (1995) traced the causal chain between IT investment and firm performance by looking at the effect of IT on intermediate variables. They proposed a two-stage model that first incorporates the impact of EDI on intermediate process outcomes, and then measures the impact of the intermediate process outcomes on aggregate firm performance. Using the MPIT database for 60 business units from 1979 to 1983, they found that IT was positively related to three of the five intermediate measures. Their results support using the two-stage model for evaluating the impact of IT on firm performance through intermediate processes.

Mukhopadhyay, Kekre and Kalathur (1995) examined the impact of EDI applications on the intermediate manufacturing processes and firm-level performance. Using EDI transaction data from 1981 to 1990 at Chrysler, they found that the launching of EDI and the penetration of EDI programs were associated with significant improvement in intermediate process outcome measures such inventory turnover, obsolete inventory and premium freight. These intermediate outcomes in turn led to significant cost savings at the aggregated level.

A "Process-Oriented" Model of Organizational Impact of IT Infrastructure

Based on the above review, we propose a "process-oriented" two-stage model to better understand the process through which the organizational impact of IT infrastructure can be

evaluated. Such a conceptual understanding of the evaluation process is critical for formulating appropriate research hypotheses. As shown in Figure 2, the impact of IT infrastructure may be captured at two levels through two sub-processes: a leverage process and a conversion process.

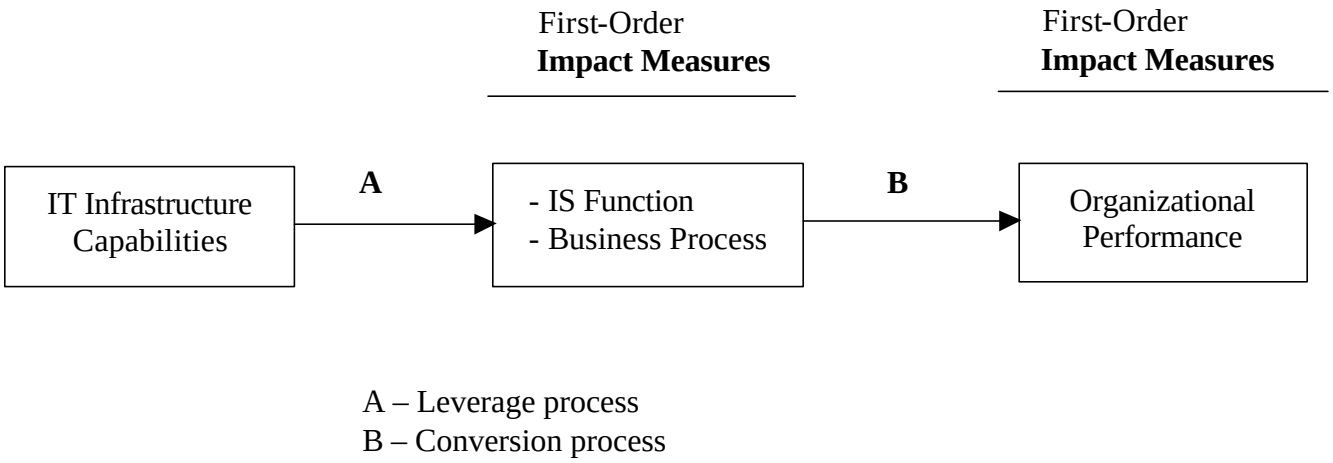

Figure 2. A "Process-Oriented" Model of the Organizational Impact of IT Infrastructure

Leverage process

The first sub-process (labeled A in Figure 2) captures the impact of IT infrastructure on the intermediate processes. This sub-process is named as "leverage process" because it reflects the organization's effectiveness in leveraging it's IT infrastructure to deliver desired performance at the intermediate level. This is the first stage of the two-stage evaluation model derived from the process-oriented frameworks discussed in the preceding review (Barua et al., 1995; Beath et al., 1994; Markus and Soh, 1993; Mooney et al., 1995; Sambamurthy and Zmud, 1994; Soh and Markus, 1995).

A basic rationale for this leverage link is that appropriate use and leverage of IT infrastructure capabilities in intermediate processes is a necessary condition for any organizational impact to occur (Lucas, 1993; McKeen and Smith, 1993; Trice and Treacy, 1986).

Since IT infrastructure is defined as the shared IT resources and capabilities that provide the foundation upon which IT applications are developed and business processes are supported, two sets of intermediate processes are considered in the conceptual model: the overall IS function and the intermediate business processes.

Conversion process

The relationship between the first-order impact measures of IT infrastructure on the intermediate processes and the second-order impact measures on organizational performance is referred to as conversion process (labeled B in Figure 2). This is the second stage of the two-stage evaluation model derived from the process-oriented frameworks. Since the ultimate goal of IT infrastructure is to improve the effectiveness and performance of the organization, the conversion process represents the aggregated organization-level business value gained from the investments in IT infrastructure.

While the leverage process represents the first-order impact of IT infrastructure, the conversion process represents the second-order impact of IT infrastructure. The effectiveness of each sub-process is a necessary condition for any positive impact of IT infrastructure to occur. There must also be a fit or complementarity between the two sub-processes. In addition, the effectiveness of the leverage and conversion processes depends on not only the organization's ability to manage the boxes and linkages shown in Figure 2 but also the fit or complementarity between these sub-processes and other organizational factors and processes.

Research Model and Hypotheses

Based on the conceptual model discussed in the previous section, a research model and a set of hypotheses are developed (shown in Figure 3). Consistent with the conceptual model, the research model and hypotheses address both the direct impact of IT infrastructure on

organizational performance and the indirect impact through mediating effects of the intermediate elements. The hypotheses corresponding to these relationships are discussed below.

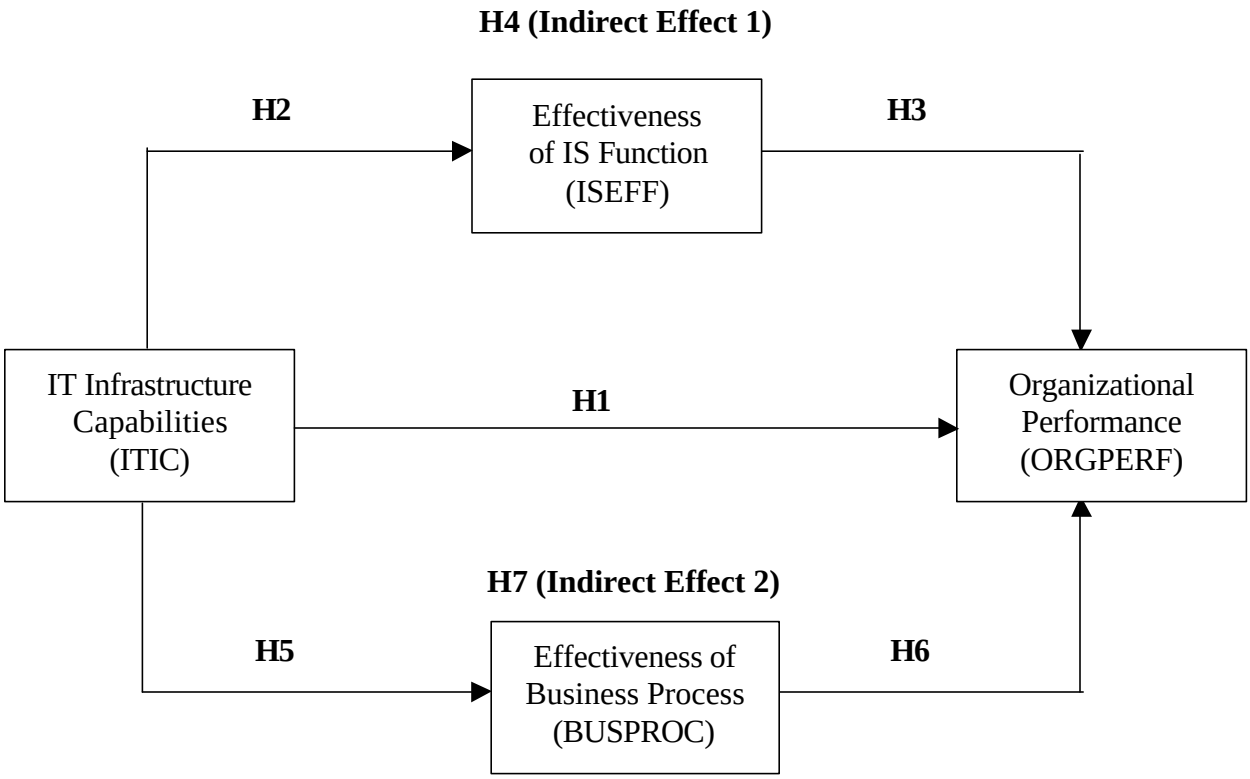

Figure 3. Research Model

Direct impact of IT infrastructure on organizational performance

The ultimate goal of investing in and implementing IT infrastructure is to improve organizational performance. IT infrastructure represents a long-term investment that provides the foundation for the development of IT applications and the implementation of IT-supported business processes (Weill, 1993). Unlike specific IT applications that are believed capable of creating direct business value (Parker and Benson, 1988; Keen, 1991) with demonstrable financial and non-financial results (Banker and Kauffman, 1988; Clemons and Row, 1988), IT

infrastructure provides the organization with long-term strategic options and flexibility (Markus and Soh, 1993; Duncan, 1995).

Therefore, the first hypothesis asserts the existence of a direct impact. Because of the inconclusive results of studies that have studied such direct impact, it is not anticipated that this hypothesis will be supported.

Hypothesis 1: The capabilities of an organization's IT infrastructure has a direct and positive effect on organizational performance.

Indirect impact mediated by IS functional effectiveness

Based on the "process-oriented" model shown in Figure 2, IT infrastructure is proposed to first have a first-order impact (leverage process) on the effectiveness of the IS function which in turn produce a second-order impact (conversion process) on organizational performance.

IT infrastructure capabilities are presumed to be a major factor that determines the effectiveness of, and the assignment of an appropriate role to, the IS function within the organization. For instance, organizations that use IS for strategic purposes may allocate more resources to IT infrastructure and expect greater effectiveness from the IS function. IT infrastructure also influences the effectiveness of the overall IS function by defining the "freedom of IT." Since the capability to develop or change IT applications is based on existing hardware and software platforms, network configurations, distributed databases and system architecture, the extent of IT infrastructure capabilities either facilitates or inhibits both innovation and the continuous improvement of IT applications and systems (Duncan, 1995). Thus, the unique characteristics of an organization's IT infrastructure make the cost and efficiency of developing and implementing IT applications different for various organizations. In organizations with an inflexible or obsolete IT infrastructure, it may be necessary to upgrade or redesign the IT infrastructure before any IT innovations become feasible, resulting in

significantly higher costs and longer development cycles. Therefore, it may be expected that the greater the IT infrastructure capabilities, the more effective and efficient the overall IS function is in meeting the organization's needs for the development and implementation of IT applications.

Hypothesis 2: The capabilities of an organization's IT infrastructure positively affect the effectiveness of the IS function.

The role of the IS function has changed dramatically because of the strategic importance that organizations place on IT. As the environment becomes increasingly competitive and dynamic, organizations increasingly use IT as a strategic weapon for competitive advantage (Ives and Learmonth, 1984). IT is used not only to support the efficiency and effectiveness of organizational structures and processes, but also to outmaneuver competitors (Bakos and Treacy, 1986) and to enable organizational transformation (Davenport and Short, 1990). As the dependence of organizations on IT increases, the effectiveness of the IS function in delivering new or changed IT applications on time and within budget become critical factors affecting organizational performance. Differences in value generated by IT infrastructure may vary across organizations because of variations in the competence of the IS function in leveraging IT investment and converting IT infrastructure capabilities into value-generating applications (Weill, 1992). Thus, the effectiveness of the IS function should affect the organization's overall performance.

Hypothesis 3: The effectiveness of the IS function positively affects organizational performance.

According to the process-oriented perspective of IT valuation, an effective IT infrastructure alone is not sufficient for enhancing organizational performance because an infrastructure cannot improve organizational performance unless it is used to deliver timely IT

applications that meet business needs (Duncan, 1995; Lucas, 1993). The mediating role of the IS function between IT infrastructure and organizational performance reflects the notion of "conversion effectiveness" proposed by Weill (1992). Even if IT infrastructure is claimed to have no direct performance outcomes at the organizational level (Markus and Soh, 1993), it may affect organizational performance by affecting the effectiveness of IT applications and systems development (Beath et al., 1994). It follows that instead of directly impacting organizational performance, an organization's IT infrastructure affects organizational performance indirectly through its impacts on the effectiveness of the IS function.

Hypothesis 4: The capabilities of an organization's IT infrastructure indirectly affect organizational performance through the effectiveness of the IS function.

Indirect impact mediated by business process effectiveness

Similarly, IT infrastructure is proposed to first have a first-order impact (leverage process) on the effectiveness of the business processes which in turn produce a second-order impact (conversion process) on organizational performance.

By isolating economically and technologically distinct activities within a business, Porter's (1985) value-chain model provides an effective framework for taking a closer look at how IT infrastructure affects particular business activities and thus provides a starting point for a detailed IT infrastructure impact analysis (Kauffman and Kriebel, 1988). IT infrastructure is unique in that it has implications for both operational and management processes (Duncan, 1995; Weill, 1993). Malone (1987) suggests that, in general, IT consists of production and coordination technologies. This proposition was supported by Lind and Zmud (1991) who found that IT support of value-chain activities encompasses two components: impact on primary activities and impact on support activities.

Since IT infrastructure permeates the entire value chain, some and perhaps even all the

activities and links in the value chain can be enhanced or transformed to provide a means of competitive advantage (Hammer, 1990; Weill and Broadbent, 1998). IT infrastructure can improve the efficiency of operational processes through automation, or enhance their effectiveness and reliability by linking them together. IT infrastructure may enable the organization to reduce cycle time and production costs, improve quality and customer service, and increase sales. Management processes may be enhanced by information sharing, timely communications, and improved decisions.

In addition, IT infrastructure provides the shared basis and foundation supporting business processes. By making business process changes either possible or impossible, IT infrastructure also represents the freedom of IT-based business applications. It follows that greater IT infrastructure capabilities would lead to greater effectiveness of the business processes that they support.

Hypothesis 5: The capabilities of an organization's IT infrastructure positively affect the effectiveness of business processes.

Organizations deliver their products and services and create value through their value chain activities (Porter, 1985; Porter and Millar, 1985). The effectiveness of the business activities and processes involved in the value chain are key factors that influence the overall performance of the organization. As the use of IT enables an organization to initiate new competitive strategies, to reduce the costs of product design, development, production, marketing, and sales, and to enhance internal and interorganizational efficiency (Bakos, 1987; Bakos and Treacy, 1986; McFarlan, 1984), it would be expected that the organization's performance in terms of productivity, market share and profitability would be improved.

Hypothesis 6: The effectiveness of business processes positively affects organizational performance.

An IT infrastructure, no matter how effective, may be meaningless unless it is used and leveraged to improve the business activities that it supports (Lucas, 1993). In other words, an effective IT infrastructure is not the end itself, but rather, is a means for reaching the end. The mediating role of intermediate business processes between IT infrastructure and organizational performance reflects another dimension of "conversion effectiveness" (Weill, 1992).

As discussed in previous sections, several frameworks have been proposed that advocate the mediating role of the intermediate business processes. For example, Sambamurthy and Zmud (1994) propose that IT creates business value by delivering new and improved products and services, transformed business processes, enriched organizational intelligence, and dynamic organizational structure. Markus and Soh (1993) contend that IT assets or infrastructure will not have any impact on organizational performance unless they are appropriately used to develop and improve products and services, redesign business processes, support better decision making, improve coordination and enhance productivity. Therefore, the impact of IT infrastructure can manifest at intermediate levels through improvements of business activities in the value chain.

Hypothesis 7: The capabilities of an organization's IT infrastructure indirectly affect organizational performance through the effectiveness of business processes.

Research Methods

Field interviews and mail surveys were utilized in the two major stages of this study. In this section, we provide an exposition of sample and data collection procedures and measurement of variables used in the study.

The field interview stage

In the first stage, interviews with both IS and business managers were conducted to gain insights about the organizational practices related to IT infrastructure management and to develop appropriate measurement. The questionnaires resulting from the first stage were then

used to collect the large sample data for testing the research model and hypotheses. Since the interviews were mainly used to better understand the various constructs, to refine the research model and to develop the instruments, no statistical analyses of the interview data were conducted.

The interviews involved managers from five companies in banking, steel, healthcare, manufacturing and insurance. In each company, two managers, one IS and the other business, were interviewed. Each interview lasted about one and one half-hours.

In interviews with the IS managers, the managers were first asked to describe their IT infrastructure architecture and the characteristics of various aspects of IT infrastructure. They were presented with an IT infrastructure analysis grid (Xia and King, 1999) and were asked to comment on this conceptualization of IT infrastructure capabilities. The IS managers were then asked to suggest possible ways to measure the characteristics of IT infrastructure and to provide an assessment of their firm's IT infrastructure capabilities.

In interviews with the business managers, the managers were first asked to describe their assessment of the roles and the impact of IT infrastructure on their IS function, business processes, and the overall performance of their organization.

These interviews provided a critical understanding of organizations' practices of IT infrastructure management. The feedback and normative recommendations from the IS and business managers not only helped refine and qualitatively validate the constructs and research model, but also confirmed the relevance and importance of this research.

Mail survey stage

The second stage of the study made use of a sample of 980 firms in a variety of industries that was randomly selected from two sources: (1) the *Corporate Yellow book* and (2) an on-line commercial database provided by Hoovers, Inc. (http://www.hoovers.com).

The CEO of each selected organization was sent a package containing a cover letter to the CEO and two unsealed envelopes. One of the two envelopes was addressed to a senior IS executive and the other was addressed to a senior business planning executive. Each envelope contained a cover letter, the appropriate questionnaire and a postage-paid business return envelope. The cover letter to the CEO explained the purpose and importance of the study, and requested the CEO to forward the enclosed envelopes to the appropriate executives. Since the IS function might be either centralized or decentralized in an organization, specific instructions were provided to the CEO for forwarding the envelopes. If the IS function was primarily carried out centrally at the corporate level for most business segments, the CEO was asked to forward the envelopes to a senior business executive responsible for corporate business planning/strategy and a senior IS executive responsible for the corporate IS function. Conversely if the IS function was carried out primarily on a decentralized basis in each business segment, the CEO was asked to select any core business segment and forward the envelopes to a senior business planning executive and a senior IS executive in the same core business segment.

To ensure the rigor of the data collection process, the survey design applied the techniques recommended by Dillman (1978). Because the survey required "matched-pair" respondents in each organization, a potential challenge was ensuring a sufficient response rate. A variety of strategies and tactics were employed to enhance both the quality and quantity of responses. The instruments were carefully designed and went through a series of pre-testing and

pilot testing. The CEO and both senior executives were ensured of the confidentiality of the information provided in the surveys. In addition, they were ensured that no sensitive information would be requested. Two customized follow-up reminders were mailed after the first mailing.

Sample Characteristics

The response rate and characteristics of the sample provided assurances that the responses were appropriate to the objectives of the study.

The response rates for total usable responses and matched responses from the business executives and IS executives are summarized in Table 1. The response rate was computed based on a formula recommended by Dillman (1978). The total response rates for the business and IS questionnaires were 28.66% and 29.81%, respectively. These response rates are considered to be reasonably good given that the respondents were senior executives. Of all usable responses, 236 pairs were matched, representing a "matched pair" response rate of 24.69%.

Table 1. Response Rate

	Business Executive		**IS Executive**	
	Number	**Response Rate**	**Number**	**Response Rate**
Total usable responses	274	28.66	285	29.81
Matched responses	236	24.69	236	24.69

Note:

$$\text{Response Rate} = \frac{\text{Usable Responses}}{(\text{Surveys Mailed} - \text{Unusable Responses} - \text{Undeliverable Surveys})}$$

A careful screening of the returned surveys revealed that all the responses were complete and useful. No unusual patterns or careless responses were identified, indicating that the

questionnaire's design was appropriate and the respondents were serious and careful in completing the questionnaires. In addition, appropriate comparisons were made with externally generated data on industry, sales, and employees to test for non-response bias. Comparisons of early respondents to late respondents were also conducted. No response biases were detected.

All of the 274 responses from the business executives were used to assess the validity and reliability of the measures contained in the business executive questionnaire. Similarly, all of the 285 responses from the IS executives were used for the validation of the measures contained in the IS executive questionnaire. However, only the 236 matched pairs of responses were used for testing the research model and the hypotheses.

The characteristics of the firms in the sample were analyzed in terms of (1) job titles of the executives who participated in the study, (2) industry representation, (3) annual sales.

Table 2 presents the job titles of the executives who completed the business surveys. In general, the respondents were business executives at high levels of their organizations. Specifically, 41.6% of the respondents were at least at the level of senior or executive vice president, 74.9% at least at the level of vice president and 88.3% at least at the level of director. The high level and the business orientation of the respondents indicate that the respondents were likely to be knowledgeable about their firm's overall business operations and were able to evaluate the effectiveness of IT from a business executive perspective.

Table 3 summarizes the job titles of the executives who responded the IS surveys. Generally, the respondents were the highest ranked IS executive in their firms. 37.6% of the respondents were CIOs, 32.3% were senior vice presidents or vice presidents of IS/IT, and 23.2% senior directors or directors of IS/IT. Overall, 92.3% of the respondents were at least at the level of director of IS/IT. The high level of the IS executives suggest that the respondents

were likely to be knowledgeable about their firm's overall IS operations and were able to provide a comprehensive assessment of their IT infrastructure.

Table 2. Job Titles of Business Executives [a]

Job Title	No. of Responses	Percent
President/CEO	30	10.9
Senior/Executive VP & CFO	38	13.9
Senior/Executive VP - Other	46	16.8
VP – Planning/Development	44	16.1
VP – Other	47	17.2
Senior Director - Planning/Development	19	6.9
Director - Planning/Development	18	6.6
Manager	25	9.1
Other	6	2.2
Missing	1	.4
Total	274	100.0

Note: a – Based on responses to the Business Executive Survey.

Table 3. Job Titles of IS Executives [a]

Job Title	No. of Responses	Percent
CIO	59	20.7
Senior VP & CIO	21	7.4
Senior/Executive VP – IS/IT	18	6.3
VP & CIO	27	9.5
VP – IS/IT	74	26.0
Director – IS/IT	66	23.2
Manager – IS/IT	15	5.3
Other	5	1.8
Total	285	100.0

Note: a – Based on responses to the IS Executive Survey.

The industry representation of the responding firms is summarized in Table 4. Firms in broad manufacturing categories (manufacturing, oil/petroleum, and utilities) account for 35%, firms in information intensive industries (banking/finance, insurance, communications, computers/software, industrial services) account for 29.9%, and other categories account for 35.1% of the respondents. The summary suggests that the sample provides an appropriate representation of a wide range of industries. Therefore, it is not likely that the results will be biased by the industry representation of the sample.

Table 5 presents the distribution of the firms by annual sales. The respondent's firms averaged $3,742 million. These average and their distributions suggest that the firms are medium to large in size.

Table 4. Industry Representation [a]

Industry	No. of Responses	Percent
Agriculture/Food Processing	6	2.2
Banking/Finance	18	6.6
Communications	14	5.1
Computers/Software	15	5.5
Distribution	5	1.8
Industrial Services	13	4.7
Insurance	22	8.0
Manufacturing	75	27.4
Medicine/Health Care	19	6.9
Oil/Petroleum	5	1.8
Restaurant/Hotel	13	4.7
Transportation	19	6.9
Utilities	16	5.8
Wholesale/Retail	25	9.1
Others	9	3.3
Total	274	100.0

Note: a – Based on responses to the Business Executive Survey.

Table 5. Annual Sales [a]

Sales ($ Million)	No. of Responses	Percent
Below 500	38	13.9
500 – Less than 1,000	55	20.1
1,000 – Less than 2,000	72	26.3
2,000 – Less than 3,000	20	7.3
3,000 – Less than 5,000	32	11.7
5,000 – Less than 10,000	32	11.7
10,000 and Above	24	8.8
Missing	1	.4
Total	274	100.0
Mean 3,742 Std 6,730		

Note: a – Based on responses to the Business Executive Survey.

Operational measures of the variables

To ensure the validity and reliability of the measurement, all constructs in the research model were measured using multiple items. In addition, whenever possible, measures that were tested and used in previous research were adopted or adapted for this study. For those variables for which no validated measures exist, new measures were created based on the literature and/or derived from the field interviews with IS and business managers. Due to the space limit, the procedures for developing the various measures will not be discussed in details.

IT Infrastructure Capabilities

There were no validated comprehensive instruments for measuring the characteristics of

IT infrastructure. Duncan (1995) and Broadbent et al. (1996) were useful references for developing the measures. Five constructs were defined and operationalized for measuring the characteristics of IT infrastructure: reach of IT infrastructure, range of shared IT infrastructure services, IS standards and procedures, flexibility of IT infrastructure, and IS management competence.

Reach of IT infrastructure refers to the extent to which the various IT components or business functions are connected through IT infrastructure (Keen, 1991). Duncan (1995) operationalized reach in terms of connectivity and sharability of IT infrastructure components (e.g., computer platforms, networks, data, and applications). In addition, Broadbent and Weill (1997) suggested that connectivity with customers and suppliers may also need to be considered in measuring the reach of IT infrastructure. Based on the literature, three items were used to assess the connectivity and sharability of IT infrastructure components. Two items were used to measure the percentage of all transactions with customers and suppliers that are electronically transmitted. These items were measured using an 11-point interval scales ranging from 0–100 percentage. To help the respondents anchor their responses, both numbers and dashes between numbers were used, each dash represented approximately 10 percentage.

Range of shared IT infrastructure services refers to the extent of organization-wide IT services provided by the corporate IS function. A list of 21 IT infrastructure services was adapted from Broadbent et al. (1996). A three-point Likert-type scale was used for capturing whether each of the 21 IT activities is primarily the responsibility of the corporate IS function (centralized), the user units (decentralized), or external vendors (outsourced).

IS standards and procedures are important for managing IT infrastructure. Duncan (1995) suggests that standards and rules for IT infrastructure configurations and compatibility are

fundamental approaches to managing the firm's capacity for sharing in terms of range. In addition, IS standards and procedures provide a framework for analysis, design and construction of IT infrastructure (Keen, 1991). These standards and procedures represent an architecture or blueprint that governs the firm's IT practices. Therefore, IS standards and procedures are used in conjunction with the range of IT service to capture the extent to which the IS function meets the organization's current need for IT-related services. Adapted from Duncan (1995), seven items were used to measure IS standards and procedures.

The flexibility of IT infrastructure was assessed in terms of compatibility, adaptability and expandability of the technological components of IT infrastructure. Fifteen items were used to measure the flexibility of platforms, networks, data and applications.

IS management competence was measured in terms of the IS staff's technical skills, managerial skills, and the flexibility of the IS function in response to changing user needs. Seven items were used to measure IS management competence.

Effectiveness of the IS Function

Effectiveness of the IS Function is defined and measured in terms of the quality of services and application projects provided by the IS function. Adapted from Srinivasan (1985), Pitt, Watson and Kavan (1985), Scudder and Kucic (1991), and Van Dyke, Kappelman and Prybutok (1997), four items were used to capture the effectiveness of the IS function. These items assess the extent to which (1) the IT applications developed by the IS function meet users' needs, (2) the IS function delivers IT applications on time, (3) the IS function delivers IT applications within budget, and (4) the IS function provides reliable systems operations.

Effectiveness of the Business Processes

Effectiveness of business processes is defined as the extent to which IT infrastructure

contributes to the various activities along the organization's value chain. Adapted from Porter and Millar (1985), Ramamurthy (1989), Grover (1990), Mahmood and Soon (1991), Chan (1992), Sethi and King (1994), Barua et al. (1995), Mooney et al. (1995), and Tallon et al. (1997), 33 items were used to measure the contributions of IT infrastructure to business processes. Based on the classification schemes proposed by Porter and Miller (1985) and Davenport (1993), these 33 items were expected to capture six dimensions of the value-chain activities. These dimensions include management processes, supplier relations, product development, production and operations, marketing services, and customer relations.

Organizational Performance

Organizational performance is defined as the extent to which the IS function contributes to the various performance measures at the organization level. Venkatraman (1989) proposed that organizational performance can be best captured by a two-dimensional scale: market growth and profitability. In a recent study, Chan et al. (1997) employed Venkatraman's instrument and suggested the instrument be split into four distinct dimensions: market growth, profitability, product-service innovation, and company reputation. Based on the literature, seven items were used to measure organizational performance.

Two separate questionnaires were developed for collecting the data within each organization. Table 6 shows the measurement instruments, respondents and constructs. One questionnaire was addressed to a senior IS executive and the other was addressed to a senior business planning executive. The IS questionnaire measured the variables concerning the characteristics of IT infrastructure which is the independent variable of the research model. The business questionnaire measured (1) the effectiveness of the IS function, (2) the effectiveness of business processes, and (3) organizational performance. The variables in the business

questionnaire represent the mediating and dependent variables.

Table 6. Measurement Instruments, Respondents and Constructs

Measurement Instruments	**Key Respondents**	**Key Constructs**
Questionnaire 1 – Capabilities of IT Infrastructure	Senior information systems executives (e.g., CIO, Vice President of IS)	Independent Variable: IT infrastructure Capabilities (ITIC) - Reach of IT infrastructure (ITREACH) - Range of shared IT infrastructure services (ITRANGE) - IS standards and procedures (ITSTAND) - Flexibility of IT infrastructure (ITFLEX) - IS management competence (ITMGT)
Questionnaire 2 - Organizational Impact Variables	Senior business executives (e.g., CEO, Senior Business Planning Executives)	Mediating Variables: - Effectiveness of the IS function (ISEFF) - Effectiveness of business processes (BUSPROC) Dependent Variable: - Organizational performance (ORGPERF)

There were two main considerations for using two separate questionnaires. First, the use of two different respondents to gather data on independent and dependent variables separately would reduce the risk of potential common method bias caused by using a single respondent (Pinsonneault and Kraemer, 1993; Zmud and Boynton, 1991). Second, since the measures were divided into two questionnaires, the length of each questionnaire would be effectively reduced, thereby reducing the time needed to complete the questionnaires, which would help to increase the overall response rate.

Data Analysis and Results

In this study, path analysis was used to explore the hypotheses about the relationships among IT infrastructure, IS functional effectiveness, business process effectiveness, and

organizational performance. Before testing the research model and hypotheses, the validity and reliability of the measures of the various constructs were assessed. Such an assessment is necessary to warrant further data analysis and to ensure that the results of the model and hypotheses testing are meaningful.

Validity and reliability of the measures

Validity is the degree to which an instrument measures the construct it is intended to measure (Kerlinger, 1973). Reliability refers to the stability of the instruments and the consistency of the measures (Kerlinger, 1973; Nunnally, 1978). In this study, content and construct validity was tested to establish the validity of the measurement. Since the main concern of this study was the internal consistency of the instruments, Cronbach's Alpha statistic was used as indicators of reliability for the measures. Since testing the instruments does not require matched-pair responses, the 285 responses from the IS executives were used to test the IT infrastructure measures and the 274 responses from the business executives were used to test the measures of IS functional effectiveness, business process effectiveness and organizational performance.

Content validity refers to the adequacy of the items in terms of covering and representing the domain of the construct being measured (Kerlinger, 1973). It implies that not only all aspects or dimensions of the construct are considered but also nothing that does not belong to the domain of the construct is included in the instrument (Churchill, 1979). Content validity is usually established in the early stage of instrument development where the initial pool of items was generated. Researchers may ensure the content validity of their instruments by clearly defining the domain of the construct and generating a sample of measures that adequately represents the various aspects of the construct. Two main sources for deriving the initial pool of measures are

previous research literature and field interviews with practitioners. Once generated, the initial pool of items may be refined and the content validity of the instruments tested using expert panels.

In this study, the initial items for measuring the various constructs were derived from an extensive literature review and some field interviews with both IS and business managers. These initial items were refined through a series of pre-testing procedures using eight doctoral students, 35 part-time MBA students, four graduate school faculty members, and four business and IS managers. Results of the Q-sort procedure and feedback from the evaluations of the expert panels were used to finalize the measures and the questionnaire format. These precautions and refinement procedures ensured the content validity of the instruments.

Construct validity refers to the extent to which a measurement instrument actually appraises the theoretical constructs it purports to assess (Carmines and Zeller, 1979). Two related concepts, convergent validity and discriminant validity, are commonly used to establish the construct validity. Convergent validity refers to the extent to which multiple methods or scales measuring the same concept are in agreement (Nunnally, 1978). A measure that correlates highly with other measures designed to measure the same construct provides evidence for convergent validity. Discriminant validity refers to the extent to which a measure is different from measures not measuring the same construct.

In this study, factor analysis and corrected-item total correlations were used to assess the convergent validity of the measures. Convergent validity for a construct is established if all items measuring the construct are loaded or clustered into the same factor. In addition, the total score of the measures for a construct is used as a criterion. The results of testing the convergent

and discriminant validity suggest that the measures possessed sufficient construct validity. Due to space limit, the details of validity test are not reported here.

Table 7 presents a summary of the Cronbach's alpha for each of the research constructs. Nunnally (1978) suggested Cronbach's alpha value of 0.7 be considered adequate for internal consistency reliability. For relatively new scale, however, Nunnally suggested that an alpha value of 0.6 is acceptable. In this study, IT infrastructure and business process effectiveness measures were new. Therefore, we decided those alpha values over 0.70 were acceptable for measures of IS functional effectiveness and organizational performance, and those alpha values over 0.6 were acceptable for measures of IT infrastructure and business process effectiveness. Table 7 shows that all variables had alpha values greater than 0.80 except for the reach of IT infrastructure (0.65). The results suggest that the measures can be considered reliable.

Insert Table 7 about here

Tests of research model and hypotheses

To ensure that the assumptions of path analysis were met and that the models being tested were not misspecified, scatter plots of the residuals were examined. The results of the residual scatter plots indicated that the patterns of the residuals were random and contained few outliers, thus, path analysis was deemed to be appropriate.

Three nested regression models were formulated to estimate the path coefficients in the research model. The effectiveness of the IS function, effectiveness of business processes, and organizational performance were each successively treated as a dependent variable in the nested models.

Table 7. Reliability of the Measures

Constructs	Reliability
IT Infrastructure Capabilities (ITIC)	
Reach of IT Infrastructure (ITREACH)	.65
Flexibility of IT infrastructure (ITFLEX)	.91
IS Standards and Procedures (ITSTAND)	.89
Range of Shared IT Infrastructure Services (ITRANGE)	.88
IS Management Competence (ITMGT)	.90
Impact Measures	
Effectiveness of the IS Function (ISEFF)	.80
Effectiveness of Business Processes (BUSPROC)	.96
Management Processes (BMGT)	.86
Supplier Relations (BSUPPLIER)	.86
Product Development (BPRODUCT)	.92
Production Operations (BOPERAT)	.89
Customer Relations (BCUSTOM)	.92
Marketing (BMARKET)	.87
Organizational Performance (ORGPERF)	.93

Table 8 and Figure 4 present the estimates of the direct, indirect and total effects of predictors on dependent variables. The percentage of variances explained by each regression model is also shown.

Hypothesis 1, as expected, was not accepted. Hypothesis 1 proposes that IT infrastructure capabilities (ITIC) has a direct effect on organizational performance. As shown in Table 8, the standardized beta coefficient of ITIC was not significant as a direct effect on organizational performance. This result is consistent with the widely-held belief that IT infrastructure does not directly produce business value (e.g., Markus and Soh, 1993; Duncan, 1995).

Table 8. Direct, Indirect and Total Effects of Predictors on Dependent Variables

	Dependent Variables					
	ISEFF	**BUSPROC**	**ORGPERF**			
Predictors	**Direct Effect**	**Direct Effect**	**Direct Effect**	**Indirect Effect 1**	**Indirect Effect 2**	**Total Effect**
ITIC	.35***	.38***	.05	.08	.27***	.39***
ISEFF			.21***			
BPIIT			.70***			
Adjusted R^2	.165	.231	.668			

Note:* P < .05, ** P < .01, *** P < .001

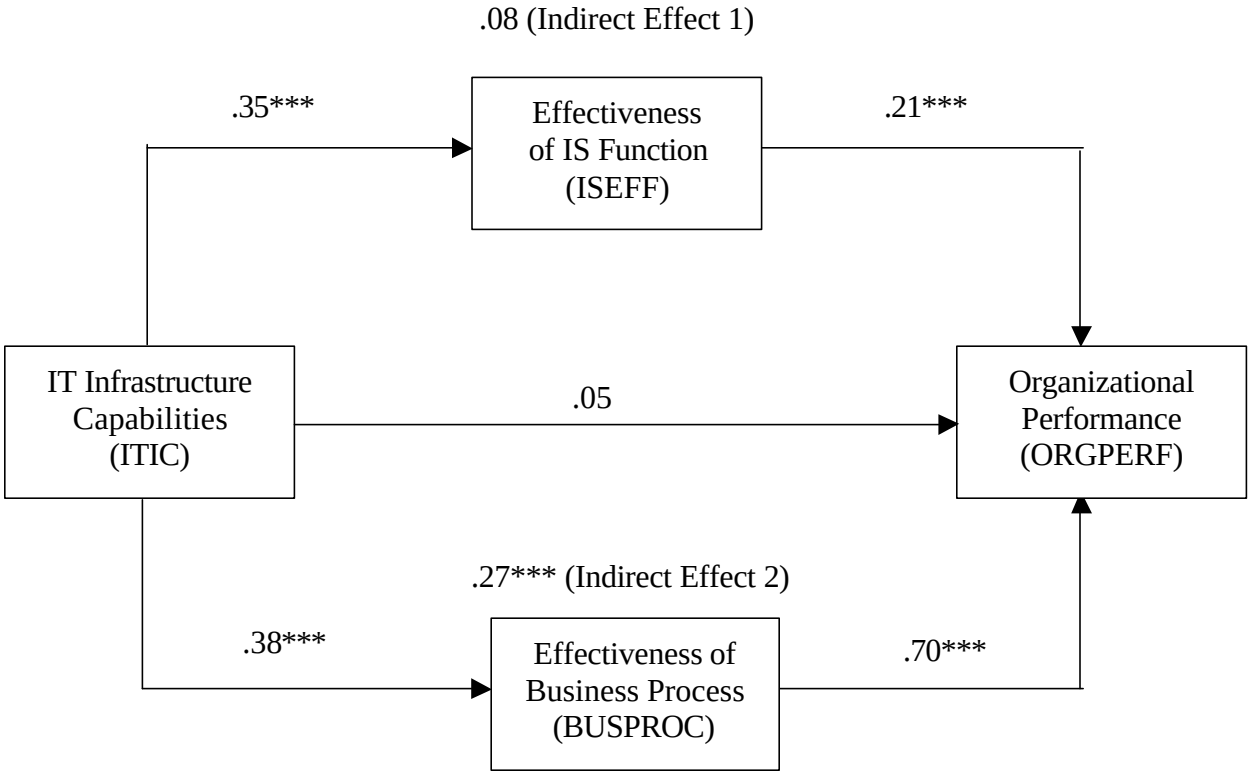

Figure 4. Model Test Results

Hypothesis 2 proposes that IT infrastructure capabilities have a direct and positive effect on the IS function's effectiveness. This is confirmed in that infrastructure capabilities had a significant direct effect (? = .35, $p < .001$) on IS effectiveness. The regression model explains about 16.5% of the variance in IS effectiveness. The direction of this relationship was positive as hypothesized. Therefore, there is sufficient evidence to support Hypothesis 2.

Hypothesis 3 proposes that IS functional effectiveness significantly and positively affects organizational performance. IS effectiveness had a standardized beta coefficient of .21 ($p < .001$), indicating sufficient evidence for the support of this hypothesis.

Hypothesis 5 proposes that IT infrastructure capabilities have a direct and positive effect on business process effectiveness (BUSPROC). The estimates suggests that this relationship existed (? = .38, $p < .001$). The regression model explains about 23.1% of the variance in BUSPROC. Therefore, Hypothesis 3 is supported by the path analysis result.

Hypothesis 6 proposes that BUSPROC has a significant and positive effect on organizational performance. This is confirmed by the path analysis which shows that BUSPROC was the most significant predictor of organizational performance (? = .70; $p < .001$).

Hypotheses 3 and 7 predict an indirect effect of ITIC on organizational performance through IS effectiveness and BUSPROC, respectively. To test these two hypotheses, the total indirect effects of ITIC on organizational performance was decomposed into the two corresponding indirect effects. The decomposition resulted in a positive but non-significant indirect effect of .08 of ITIC on organizational performance through IS effectiveness, indicating that Hypothesis 3 was not supported. However, the indirect effect of ITIC on organizational performance through BUSPROC was significant and positive (0.27, $p < .001$), providing sufficient support for Hypothesis 7.

Discussion and Conclusion

The direct effect of IT infrastructure capabilities on organizational performance was not supported. This is consistent with the inconclusive results that have been found in such "direct effect" studies. Thus, even with the improved measure of the independent variable (i.e., ITIC rather than investment levels), no direct effect can be confirmed.

Although the importance of IT infrastructure in supporting the operation of IS functions and the development of IT applications has often been proposed (McKay and Brockway, 1989; Keen, 1991; Weill, 1993; Duncan, 1995, Broadbent, et al., 1996), no empirical results have previously been produced to support this notion. The result of this study provides important empirical evidence that IT infrastructure is a critical factor that influences the effectiveness of the IS function.

IT infrastructure has been recognized as an important factor in supporting business operations (Keen, 1991; Duncan, 1995; Broadbent, et al., 1996) and facilitating organizational change (Davenport, 1993). However, the impact of IT infrastructure on business processes had not previously been empirically investigated. This finding provides empirical evidence that IT infrastructure capabilities are directly related to the effectiveness of business processes.

The test results also provide evidence for the effect of IS effectiveness on organizational performance. This finding provides further validation to the notion that as a business within the business, the IS function plays an important business role influencing organizational performance (Kwon and Zmud, 1987).

The strong impact of BUSPROC on organizational performance provides an empirical validation to the process-oriented model of evaluating the organizational impact of IT

infrastructure. This finding suggests that IT infrastructure will not improve organizational performance unless it is used effectively to improve the business processes it supports.

These results suggest that although both the IS function and business processes mediate the relationship between IT infrastructure and organizational performance, business processes play a much stronger role in converting IT infrastructure capabilities into organization-level gains. This result is not surprising since BUSPROC was a much more powerful predictor of organizational performance than was IS effectiveness.

Overall, the results clearly indicate that the effect of IT infrastructure capabilities on organizational performance is primarily through the intermediate impacts. Thus, there is no "magic bullet" of IT investments, or even of creating IT infrastructure capabilities. The impact of investment is on creating capabilities which are used to enhance the value creating capacities of business processes and the effectiveness of the IS function.

Thus, this study suggests that the focus of management should not be on making IT investments or even on the more-sophisticated approach of creating specific IT infrastructure capabilities. Rather, it is the emphasis that is put on achieving intermediate goals in terms of the manner in which IT infrastructure capabilities are used to create a more effective IS function and more effective business process which should be primary foci of management attention.

These results serve to refute the productivity paradox and to support the wide-body of anecdotal evidence that reflects a positive impact of IT on organizational performance. Prior attempts at measuring the impact have proved to be less than encouraging, in part because they focused on the direct impact when it is the indirect impacts that are of paramount importance.

The study suggests that management is ill-advised to concentrate on measuring only the direct impact of IT investments since such measurements may severely undervalue the role of IT.

It is likely that the impact of IT can only be adequately assessed in terms of the intermediate impact on IS effectiveness and on business process effectiveness as complements to whatever direct benefits that may exist.

The results also serve to emphasize the importance of using sophisticated multi-attribute measures of IT infrastructure capabilities, IS functional effectiveness, business process effectiveness and organizational performance. Such measures are much more likely to reveal relationships than are simplistic measures such as IT investment levels, productivity and financial performance.

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