

**THE ROLE AND VALUE
OF INFORMATION TECHNOLOGY
INFRASTRUCTURE: SOME EMPIRICAL
OBSERVATIONS**

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The Role and Value of Information Technology Infrastructure: Some Empirical Observations

Abstract

Information technology (IT) infrastructure is a critical component of the IT portfolio. The role and value of IT infrastructure is not well understood. This paper explores these issues via the IT and public infrastructure literatures as well as observations in five large organizations. The provision of IT infrastructure appears to be a strategy companies have adopted to find an economically sensible compromise between complete centralization and complete decentralization of IT. Specifically, three questions are addressed: 1. What is a clear definition of IT infrastructure? 2. What benefits do firms expect to get from IT infrastructure investments? 3. How are IT infrastructure investments identified and justified? The result is a model of the role and business value of IT infrastructure. Two types of infrastructure are identified: firm-wide and business unit IT infrastructure. The model also distinguishes between different roles firms identify for IT infrastructure and suggests different benefits profiles will result. A number of propositions and implications for management policy are derived from the model.

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1. Introduction

All information technology (IT) is not alike. IT investments are made to achieve a broad range of management objectives. Managers expect IT investment to influence performance in a number of ways. These include to :

- . Provide a competitive advantage by facilitating rapid response to changing needs in the market place.
- . Provide timely and accurate information to facilitate better decision making.
- . Reduce the cost of doing business by substituting capital for labor often by automating the transactions of the firm.
- . Allow the firm to compete in marketplaces requiring a specific technology (e.g. ATMs for banks, EDI for parts suppliers).
- . Provide flexibility so that firms can handle a wider array of customers' needs without cost increases.
- . Provide a technological platform to enable other business systems to be produced.

It is IT for these last two management objectives that is the focus of this paper. This type of IT is often referred to as **infrastructure**. Very little is known about the role and especially the payoff of IT infrastructure investments. Despite this uncertainty large investments are made in IT infrastructure as the enabling foundation for other business systems [McKay & Brockway 1989]. What distinguishes infrastructure is that it is IT shared throughout the firm. Infrastructure investment is long-term in nature, often takes advantage of economies of scale of centralized investment, and supports a shared firm-wide vision. McKay and Brockway estimate IT infrastructure accounts for between 35 and 40% of total IT investment in the average firm. Generally the business units or functional areas require infrastructure but are unwilling or unable to build their own for

technical or financial reasons. Typical examples of infrastructure are the telecommunications network, a general purpose database system (e.g. DB2), centrally located mainframe computers and shared data definitions.

IT infrastructure is becoming more important as an issue for information systems managers. An annual survey of information systems executives who are members of the Society of Information Management (SIM) identified IT infrastructure as increasing in importance [Niederman, Brancheau & Wetherbe 1991]. Building a responsive IT infrastructure was ranked sixth in importance and was the only new issue in the top ten issues raised. The challenge is providing a flexible infrastructure at low cost which is continually evaluated and updated with the emerging new technologies.

The purpose of this paper is to address three questions.

- a. What is a clear definition of IT infrastructure?
- b. What benefits do firms expect to get from IT infrastructure investments?
- c. How are IT infrastructure investments identified and cost justified?

Each question is addressed in turn via the literature and empirical observations. Two bodies of literature are useful: the IT literature and by analogy the public infrastructure literature. The result is a model of the role and the process by which IT infrastructure provides business value. A number of propositions and management implications complete the paper.

The crux of the empirical observations were based on discussions with managers from five firms. Generally the managers were the chief information officer or the information systems manager. These firms were all large, profit seeking and (except one) in

financial services. However, it is hard to separate out these influences from those acquired from seminars¹, talks, conferences, advising work, executive teaching and MBA class visits of information systems executives. Some discussions with companies were brief where the answers to my questions were quick, clear and pedantic. Other discussions were long and detailed and were followed by my careful examination of supporting documents such as the information systems plans or information systems architectures.

2. What is a clear definition of IT infrastructure?

Research on investments in information technology infrastructure is still in its infancy. To date the IT literature has given scant attention to IT infrastructure with most references appearing in the last few years. An on-line search of the ABI/Inform database (which includes most of the leading information systems journals) revealed only a handful of papers. One explanation is that the importance of IT infrastructure has only surfaced recently as we have witnessed the decentralization of the use of IT in organizations. Kit Grindley of the London School of Economics has studied this trend. In 1980 virtually 100% of IT spending was from the centralised information systems group. In 1990, in a study of 102 major European, U.S., Japanese and Australian companies he found that one-third of the IT spending was outside the centralised information systems group [Australian Financial Review 1992]. One important role of the centralized IT department in this decentralized environment is to provide the IT infrastructure or platform as an enabling base for the business units [Ahituv & Neumann 1990, pp. 199] [Keen 1991].

IT infrastructure is the enabling foundation of shared information technology capabilities upon which business depends

¹ A number of these insights came from sponsor company presentations at the M.I.T. Center for Information Systems Research's (CISR) Endicott House Seminar on Business Process Redesign on April 1-3, 1992.

[McKay & Brockway 1989]. This shared characteristic differentiates IT infrastructure from other IT which directly performs the business processes² (e.g. manage inventory) and is used only in a few areas in the organization. Also IT infrastructure investments are usually large and long-term in nature.

The IT infrastructure includes the hardware, operating software, communications, other equipment and support required to enable business applications [Turnbull 1991]. Also required is the mortar to bind all the IT components into robust and functional IT services which make up the infrastructure [McKay & Brockway 1989]. The mortar includes a specific body of knowledge, skill sets and experience and will be referred to in this paper as human IT infrastructure. The human IT infrastructure provides the policies, planning, design, construction and operations capability necessary for a viable IT infrastructure.

An understanding of the components and structure of IT infrastructure is still in development, however, a useful model is provided by McKay & Brockway [1989]. Infrastructure is composed of two layers (see figure 1). At the base are the IT components (e.g computers). These are commodities readily available in the market place. The second layer above is a set of shared IT services such as universal file access, electronic data interchange (EDI) or a full service network. The IT components are combined into useful IT services that can be used as building blocks for business systems. The human IT infrastructure of knowledge, skills and experiences molds these two levels together into the firm's IT infrastructure.

The dimensions of the IT infrastructure can also be specified. Keen [1991] defines an organization's IT infrastructure as having

² A useful definition of a business process is provided by Davenport and Short [1991]. A business process is "a set of logically related tasks performed to achieve a defined business outcome" Processes have customers (either internal or external to the firm) thus crossing organizational boundaries and have defined business outcomes.

both reach and range. Reach determines the locations the infrastructure can link, from local work stations and computers within the same department to linking functional areas within the firm. Greater reach links the firm's customers and suppliers both domestically and internationally. The conceptual ideal of reach is to link to anyone, anywhere.

Range determines the breadth of information that can be directly and seamlessly shared across the systems and services. For example, low range limits the computer-based sharing of information to simple data transfer. Ideal range would allow any computer-generated transaction, document, file or message to be used on any other system. The combination of the available reach and range defines the dimensions of the firm's IT infrastructure. Business needs determine the extent of reach and range required.

IT infrastructure differs from conventional application projects on a number of aspects. Grossman & Packer [1989] have identified five useful dimensions. Firstly, the champion or driver for IT infrastructure is usually the senior IT executive while for a business system the champion is often (or perhaps should be) the business manager. Secondly, the purpose of the business systems is to deliver business functionality while the purpose of IT infrastructure is to provide a platform for future business applications. Third, the scope of a business system is narrower, usually supporting one business process, product or function. The scope of IT infrastructure is much broader crossing most functions and products.

Fourth, the design requirements for the business systems must fit within the existing IT infrastructure whereas IT infrastructure projects have the objective of redefining (and removing restrictions) from the firm's IT capability. Finally, the management process is quite different. For business systems the objective is to eliminate uncertainty as part of the specification process. IT infrastructure projects must cope with

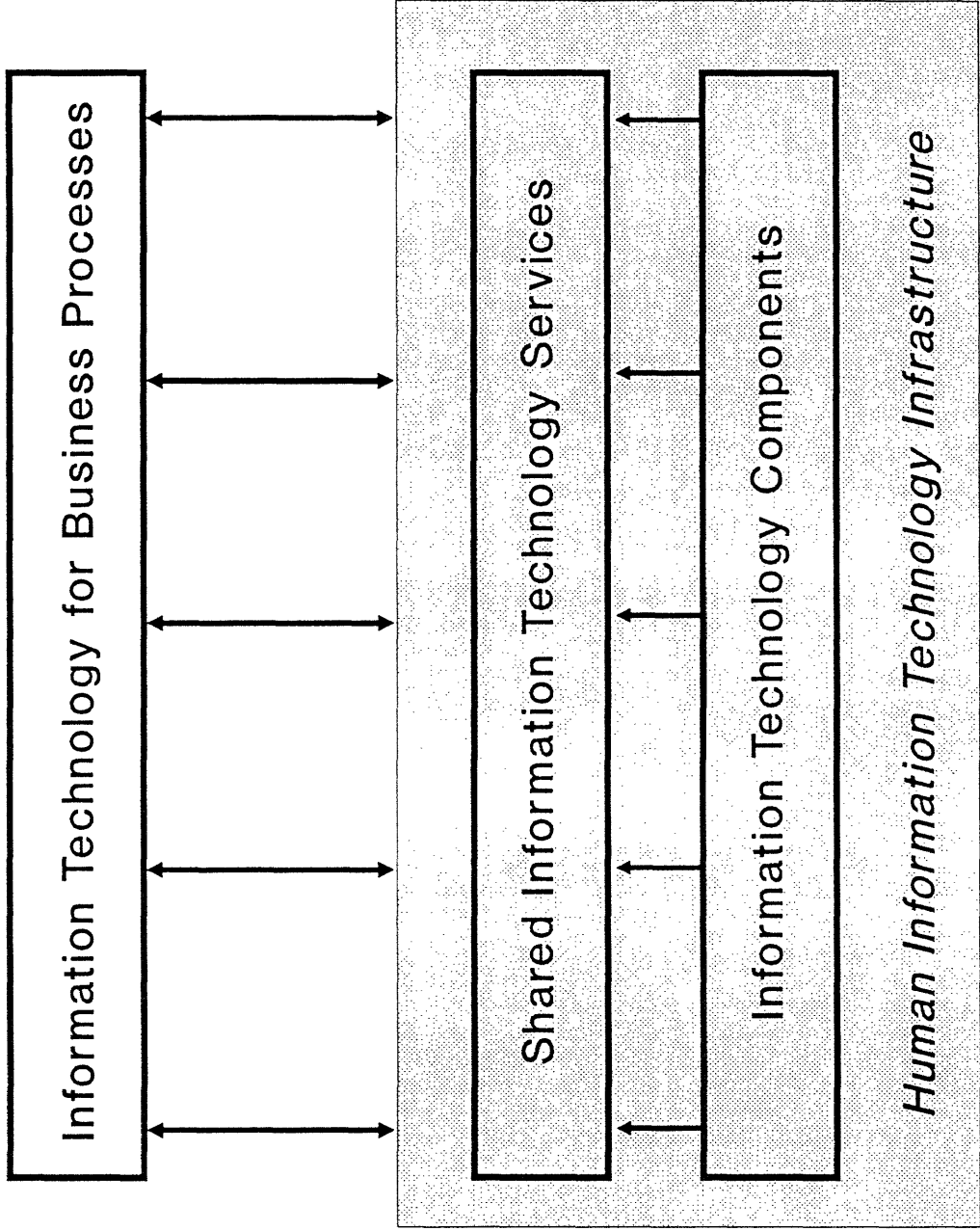


Figure 1: The Structure of IT Infrastructure

uncertainty of future needs. IT infrastructure investments require decisions as to how flexible, and thus tolerant of uncertainty, to make the infrastructure.

2.1 Empirical Observations

The general definition of IT infrastructure was quite consistent across all the firms. IT managers thought of IT shared across the entire organization as part of infrastructure. In all cases the bulk of the IT infrastructure was provided by the centralized IT function.

Generally, managers thought of these investments as being very large, having long lives, and enabling the production and operation of business systems. The following ways of conceptualizing IT infrastructure were observed:

- a. IT infrastructure is all centralized IT investments that do not directly perform a business function. This was the most common view and included all telecommunications, mainframes, operating systems, development languages (e.g. Cobol), general purpose databases, data definitions, productivity tools such as CASE, software and hardware support, electronic mail and the associated human IT infrastructure. The associated expertise included both technical expertise and managerial expertise. The technical expertise relates to the operation and integration of the IT components. The managerial expertise includes the IT planning process, scanning for new technology, budgeting and managing the interaction with other groups in the firm.
- b. IT infrastructure is the delivery by the information systems department of the core, enabling IT services. IT infrastructure is delivered at agreed service levels for a negotiated price to the business units or functional areas. The agreed service levels typically cover issues such as: the percentage of uptime of the network, the average response time for standard queries and the number of days to produce regular reports at the end of each management cycle.
- c. The inter-linked business processes which make up the business define the organization and link the firm's customers and suppliers. The IT infrastructure spans and

supports all these business processes and provides an enabling base of information systems.

- d. There are two distinct types of IT infrastructure: base infrastructure and shared systems. Base infrastructure is the networks, data center and non-specific IT capacity. Shared systems are the business systems that are provided centrally for all business units such as the general ledger system.
- e. In one very large organization with several business units there were three levels of information systems: corporate data centers, business unit data centers and IT investments (including minicomputers) in the functional areas within the business units. IT infrastructure was provided by corporate for the entire corporation. In addition, further IT infrastructure was provided for the functional areas by each business unit's IT group. Thus from the functional areas perspective IT infrastructure include both the business unit and corporate data centers. However, from the perspective of the business unit the IT infrastructure was provided only by the corporate data centers.

Precise definitions of what is and is not infrastructure varied from firm to firm. What is included in IT infrastructure appeared to depend on the number of business units and also the way the information systems function was organized in the firms.

Combining the literature and empirical observations a definition of IT infrastructure can be summarized as:

the base foundation of IT capability budgeted for and provided 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.

The key distinguishing features of infrastructure are:

- . infrastructure is shared across most functional areas or business units,
- . infrastructure is budgeted for and provided by the information systems function,

- . infrastructure is necessary investment that business units or functional areas are unlikely to make,
- . infrastructure investment is typically large, long-term in nature and takes advantage of economies of scale,
- . infrastructure is the enabling foundation for application systems that support the business processes,
- . once in place infrastructure is costly to change in both financial and political terms.

It is helpful to distinguish between firm-wide and business unit infrastructure. Firm-wide infrastructure is shared across all the business units and is provided by the corporate IT function. Business unit (local) infrastructure is shared by the functional areas in one business unit and may be provided by the business unit or the corporate IT function.

What is infrastructure depends on where in the organization you are placed. For example, the chief financial officer (CFO) in the life insurance business unit in a large insurance company has under her control (i.e. budgets for) a number of information systems to perform functions such as accounts receivable. To enable these systems she utilizes both business unit and firm-wide infrastructure. The business unit infrastructure is provided by the information systems group in the life insurance business unit and includes printing, development expertise, and local area networks. The firm-wide infrastructure is provided by the corporate information systems department and includes a wide area network, mainframes, electronic mail and the provision of architectural standards to ensure compatibility. The corporate information systems department operates as a utility delivering IT infrastructure at agreed service levels at negotiated prices. All this infrastructure is essential for her to manage accounts receivable effectively. If the infrastructure were not provided the CFO would have to create her own infrastructure which would

be less cost effective. Alternatively the CFO could outsource the infrastructure or perhaps do without.

In contrast, from the perspective of the information systems group in the life insurance business unit, infrastructure is the services provided by the corporate information systems department.

The provision of IT infrastructure appears to be a strategy companies have adopted to find an economically sensible compromise between complete centralization and complete decentralization of IT. The provision of an IT infrastructure enables the tailoring of information systems promoted under a decentralized IT structure. At the same time an IT infrastructure takes advantage of the economies of scale inherent in IT and promotes a firm-wide architecture.

The provision of a reliable IT infrastructure implies an architectural responsibility. Sufficient standardization of computing is required to ensure the business units and functional areas can take advantage of the infrastructure. Therefore a firm-wide IT architecture is an integral part of providing an IT infrastructure. Earl [1989] defines the IT architecture as "the technology framework which guides the organization in satisfying business and management information needs. ... IT architecture is the framework for analysis, design and construction of the IT infrastructure which guides an organization over time". Earl suggests a typical IT architecture has blueprints for the computing, data, communications and the application systems of the organization.

3. What benefits do firms expect to get from IT infrastructure investments?

The precise business benefits of the IT infrastructure are difficult to specify. The value of IT infrastructure is generated by enabling information systems to support business processes but not providing business benefits directly [Parker & Benson 1988].

In addition, the value of IT infrastructure is to provide and determine the business degrees of freedom [Keen 1991]. A comprehensive IT infrastructure provides flexibility in meeting the incipient trends of the marketplace.

For example, Otis Elevators revolutionized the service side of the elevator industry with their highly acclaimed computer-based customer service system, "Otisline" [Otisline 1990]. Otis Elevators was able to produce "Otisline" at least four years faster because of the existence of an IT infrastructure including a flexible database named the Service Management System (SMS). When the database was first installed "Otisline" had not been conceived. Sufficient flexibility was incorporated into the design to enable the production of "Otisline" in a much shorter time than starting from scratch. Valuing the infrastructure before "Otisline" would have been very difficult. However, the value of the flexibility of the investment is clear in hindsight. The four year break on the competition was a significant advantage in the market place.

Building in flexibility, such as the SMS database at Otis, adds cost and complexity but provides a business option that may be exercised in the future [Kambil, Henderson & Mohsenzadeh 1992]. Otis exercised their option and added the application systems supporting "Otisline" generating significant business benefits to the company.

Using Keen's [1991] concepts of reach and range is helpful in understanding the flexibility provided by infrastructure. An IT infrastructure of greater reach and range, beyond what is currently required by the business units, provides a flexibility or slack for future needs. The existence of the flexibility allows far more rapid response to an emerging business need. One reason firms invest in infrastructure is to buy flexibility.

Thus the IT infrastructure is a major business resource and perhaps one of the few sources of a long-term competitive advantage [Keen 1991]. Good infrastructure is not a commodity and thus difficult to duplicate. The human IT infrastructure of knowledge and skills and the IT management vision provide much of the value added of IT infrastructure.

Flexibility of IT infrastructure is illustrated in a case study of TRW's Space and Defense Sector's telecommunications network [Railings and Housel 1990]. TRW successfully implemented a large telecommunications network as part of their IT infrastructure. The aims included the creation of the flexibility to reconfigure the network to meet any organization structure. TRW valued this flexibility as significant changes in organization structure were anticipated.

Earl [1989] defines the building of this flexibility as an IT infrastructure-led strategy. This type of strategy is concerned with providing telecommunications networks, rationalizing data standards and providing a sound foundation for the business systems. Information systems managers may follow this strategy rather than second guess the precise and changing requirements of the business. Earl suggests that many UK banks adopted this strategy of building flexible IT infrastructures upon which new products and services could easily be added. "An infrastructure-led approach worked because the business processes became IT based". Earl identified a number of interesting characteristics of this approach. Firstly, capital investment in IT never ceases.

Secondly, the information systems strategy cannot be project-based as integration, dependencies, and architecture are important. Finally, in time the business strategy and the information systems strategy become indistinguishable.

What firms expect to get from their IT infrastructure investments will also depend on whether it is viewed as a strategic resource. Venkatraman [1991] suggests that firms view the role of IT infrastructure in one of three ways : *independent*, *reactive* or *interdependent*. In an *independent* perspective the development of infrastructure takes place outside the strategic context. Infrastructure is viewed as a utility and is treated as an administrative expense. Firms with a *reactive* perspective develop infrastructure in response to a particular strategic thrust. Infrastructure plans are derived from the business plans and consequently infrastructure is treated as a business expense.

Firms with an *interdependent* perspective develop and modify infrastructure in constant coalignment with the strategic context. Changes in infrastructure signal possible changes in strategies and vice versa. IT infrastructure identifies and responds to business strategies and is viewed as a business investment.

View of IT Infrastructure	Expected Benefits
Independent	Cost savings via economies of scale
Reactive	Short term business benefits
Interdependent	Long-term flexibility

Table 1: Expected Benefits from IT infrastructure

The different views of IT infrastructure dictate different expectations for benefits and described in table 1.

3.1 Public Infrastructure

An interesting and useful analogy to help understand the benefits of IT infrastructure is public infrastructure such as roads, bridges, sewers, hospitals, schools and public buildings. While investigating the role of IT infrastructure, Keen³ studied the development of the railroads in the U.S. He points out the difficulty in directly measuring the business value of the railroads. The business value of applications enabled by the railways is clear: freshness of vegetables, improved production time of newspapers, and reduced travel time to market. Keen makes the same argument for IT infrastructure. McKay and Brockway [1989] also note the analogy of public infrastructure to IT infrastructure. Both infrastructures are relatively large investments with long lives. Both are believed to add to the community in ways that could not be achieved through end user or private investment. Understanding more about the role and value of public infrastructure is very helpful in understanding the role of IT infrastructure.

National Infrastructure

There have been a number of very careful economic studies of the value of public infrastructure. At the international level a strong indicator is the relationship between public infrastructure investment (as a percentage of gross domestic product) and the annual growth of labor productivity. A simple regression of these two indicators, for the "G7" countries, indicates a highly significant relationship (a slope co-efficient of 0.47, T-statistic of 3.98). Countries with higher public infrastructure investment had higher productivity. During the period from 1973 to 1985 Japan had both the highest public

³ Reported in Computerworld December 24/January 1, 1991 based on an interview with Peter G.W. Keen, Executive Director of the International Center for Information Technologies in Washington D.C.

infrastructure investment and labor productivity while the U.S. is the lowest of the seven countries on both these measures [Aschauer 1989].

At the national level Aschauer [1989] also shows a significant statistical relationship between the stock of U.S. public infrastructure and output per unit of private capital. Thus infrastructure leverages private investment to provide a greater return. A similar relationship was demonstrated between the stock of public infrastructure and productivity growth. Over the period 1950 to 1985 the investment in public infrastructure tracks and slightly precedes national total factor productivity. The amount of core infrastructure of streets, highways, airports, sewers, mass transit, water, etc., has strong explanatory power of national productivity. This effect seems robust also by economic sector. For example, Deno [1988] supports this finding specifically for manufacturing output.

The size of the benefits of infrastructure has also been estimated. In examining the sluggish labor productivity of the 1970's Munnell [1990a] found a strong positive relationship between the U.S. stock of public infrastructure and labor productivity. Munnell found that a 1% increase in public infrastructure investment resulted in labor productivity increases of between 0.31 and 0.39%. Furthermore, the shortfall in public capital investment appears to be currently dragging down labor productivity. It is clear that infrastructure investment increases the return on private capital and thus will stimulate new private investment [Aschauer 1989].

The rationale for public infrastructure investment is that these services will not be produced by the private market [Munnell 1990a]. Private corporations and individuals generally are not motivated to provide their own infrastructure particularly when the infrastructure exists in other regions. The condition of the infrastructure can be as important as its existence. A highway in

poor condition can reduce the productivity of private capital and labor in the form of added time for journeys and wear and tear on vehicles. Maintenance as well as initial capital investment are also critical for infrastructure.

Regional Infrastructure

At the state and regional level the evidence is equally strong. Munnell [1990b] studied the differences between regions in the U.S. There was overwhelming evidence that public capital has a positive impact on private sector output, investment and employment. Estimating the size of the effect, Munnell reports that \$1000 more investment of infrastructure per capita resulted in 0.2% increase in annual employment growth. It is not surprising that the state which goes to the trouble of building roads, sewers, airports, water supply systems, hospitals and schools will attract more new firms. Thus public infrastructure matters in firm location decisions and effects employment growth.

The effect of regional infrastructure is also pronounced in terms of the level and productivity of private investment. One dollar invested in public infrastructure appears to increase private investment by 45 cents. Larger infrastructure investment also improves the productivity or return on the private capital investment providing a leveraging on the firm's private investment. Public infrastructure investment also appears to come before a pick-up in economic activity [Munnell 1990b].

Generalizing from these findings suggests that to attract more firms a region should invest in greater infrastructure. The firm's private investment is leveraged by the infrastructure producing employment growth and prosperity which in turn provides a tax base for future infrastructure investments.

Interestingly, the positive effects of public infrastructure are most pronounced in declining regions [Deno 1988]. This suggests infrastructure can prove a powerful policy tool for revitalizing declining areas. Policies can target particular industries which

benefit and then pass on the savings to the general community. The U.S. federal-aid highway infrastructure investments between 1950 and 1973 had a strong and positive effect on the productivity of trucking [Keeler & Ying 1988]. Fierce competition in the industry ensured that these benefits would be passed on to the economy.

The benefits of infrastructure are not without limits. Too much infrastructure will deter private investment. The balance and timing are critical.

3.2 Comparing Public Infrastructure and IT Infrastructure

The analogy between public infrastructure and IT infrastructure is compelling. There are striking similarities:

1. Both IT and public infrastructure are provided by a central agency funded by some form of taxation.
2. Both types of infrastructure require large investments and are long-term in nature.
3. The central agency in both cases provides an essential service that users would generally not be motivated or able to provide.
4. Both types of infrastructure enable business activity by the users otherwise not economically possible.
5. Both types of infrastructure must be in place often before the precise business activity is known. Thus flexibility is valued in both types of infrastructure.
6. Both types of infrastructure are difficult to cost justify in advance as well as to show the benefits in hindsight.
7. The right amount of investment is a delicate balance for both types of infrastructure. Too little will lead to duplication, incompatibility and non-optimal use of resources. Too much will discourage user investment and involvement and may result in unused capacity.

Given the similarities of the two types of infrastructure it is reasonable to expect that many of the benefits demonstrated from public infrastructure can accrue to IT infrastructure. By analogy, it is reasonable to expect IT infrastructure:

- . will improve productivity of user groups
- . leverage user groups own IT investment
- . enable new business needs to be met more rapidly.

3.3 Empirical Observations

There was agreement on the expected benefits of IT infrastructure investments in terms of information systems cost and services. Fundamentally, the objective was to provide shared IT services at reasonable cost. The level of specification of the service varied greatly.

In one firm the information systems department went to great lengths to negotiate and agree on the level of service with its internal clients. Levels of service included up-time, data transfer rates, back-up frequencies and response times. The price for infrastructure (per unit) was guaranteed for the coming year. This firm viewed infrastructure as *independent* and the information systems department performed a traditional support role. This firm saw that the main objective of IT infrastructure was to take advantage of the economies of scale available from the centralized purchase of IT components and provision of IT services.

Firms which viewed infrastructure as *reactive* or *interdependent* also mentioned the cost advantages but also spoke of other benefits to the business units. A number of business benefits were mentioned. These included:

- a. Reduced time to market for new products.

A benefit identified by most of the firms was that the existence of infrastructure enabled new products to be brought to market more rapidly. This speed was particularly valued in the financial services sector which has seen a proliferation of new products in recent years.

- b. Enables later business projects at lower cost.

One firm identified that the existence of infrastructure actually reduced the marginal cost of future projects. This was possible as infrastructure investments were funded centrally without chargeback to the businesses. The existence of a substantial IT infrastructure will significantly alter the financial attractiveness of future IT projects. If the IT infrastructure is considered a sunk cost, future IT projects directly related to the business processes will appear artificially cheaper. Some firms address this by levying an infrastructure tax on all new systems projects.

- c. Provides organizational flexibility for later and unexpected uses.

Several of the firms invested in IT infrastructure to provide organizational flexibility for business needs that had not, as yet, been identified. The IT managers in these firms saw their role as providing a flexible IT platform. These managers felt they would be viewed as successful by the business units if the IT infrastructure was available to meet new business needs faster and cheaper than the competition.

A number of managers, unable to be more precise, articulated the main benefit as avoiding the, as yet unknown, consequences of not investing! This approach was applied both to new technologies as well as upgrades of existing systems.

In summary, all three of Venkatraman's categories of a firm's view of the role infrastructure were observed. It is not clear that managers were aware of or articulated one of these views. Rather the actions of the firms were examples of behavior consistent with one of the roles of infrastructure.

4. How are IT infrastructure investments identified and cost justified?

IT infrastructure often does not provide direct business performance benefits. The benefits are derived from the business systems connected to and enable by the infrastructure. Traditional methods of capital expenditure justification, such as discounted cash flow are thus not well suited to IT infrastructure for three reasons.

- a. It is almost impossible to specify with confidence the future income stream from the investment.
- b. IT infrastructure investment occurs in the form of specific projects such as a new data base management system or a telecommunications upgrade. In contrast, business value is derived from the interaction of several independent IT infrastructure investments and business systems. This complex relationship confounds the justification process.
- c. Projects with long lives are often less attractive when using the discounted cash flow procedures. Firms often use artificially high hurdle rates for the judging the worth of an investment [Kaplan 1986]. In times of capital rationing this bias is more common and often used as a screening process. The longer life projects, like IT infrastructure, are more severely penalized by the compounding effect of the higher hurdle rates.

Wrightman [1990] describes one approach to funding infrastructure adopted by Zellers Inc. a Canadian mass merchandiser. Zellers created Club Z, a frequent buyers program requiring a major IT effort. Zellers did not have the IT infrastructure on which to implement Club Z. Zellers justified a broad-based IT infrastructure investment based on the expected benefits from Club Z. The IT infrastructure could then be used to support other business systems badly needed by Zellers.

Recently some attempts have been made to apply financial models to this question of infrastructure. Dos Santos [1991] likens some IT investment to buying a call option on a traded security as it provides an option for the firm to invest in future projects. The IT infrastructure investment enables future projects to generate value. Dos Santos presents a model that prices such an option for a firm.

Kambil, Henderson and Mohsenzadeh [1992] make the case for firms to consider IT infrastructure as "real options". They provide an example of a hospital acquiring an option to implement hand-held computers by investing in IT infrastructure such as a local area network and a data architecture.

This options approach to valuing IT infrastructure is promising and is conceptually very helpful to managers. However, the understanding of the approach is not fully developed and the data required to estimate the options is difficult to obtain, limiting its applicability.

4.1 Empirical Observations

"Funding IT infrastructure is not a popular activity in this company" was a typical response from all the companies. Most of the organizations observed did not use formal discounted cash flow methods to justify IT infrastructure investments. The most common process was that the information systems department consulted with all the businesses (in one case over 40 different businesses) and tried to understand the future business needs. Via the information systems planning process these business needs were translated into a multi-year IT budget. The information systems department has the budget approved (or otherwise) by corporate. The information systems department is then often free

to invest in IT infrastructure with no further external justification.

This process is made more difficult by the often different lengths of time a typical business strategy and IT infrastructure investment are current or usefull. Many IT infrastructure investments have 7-10 year lives while businesses strategies can change each year or two.

The justification rationales used included:

- a. Necessary to keep up with technology.

A strong motivation amongst the technical IT managers was to keep the infrastructure current with new technology. Having new technology for its own sake was certainly part of the motivation. Also an optimism often existed that a particular new technology would provide great value and thus a pilot project was initiated.

- b. Necessary to provide the agreed service levels to our internal customers.

- c. An essential part of the infrastructure that is required by the business as identified during strategy discussions with the businesses.

- d. Infrastructure that is expected by the information systems department to be important to the business.

This type of infrastructure was not motivated by the expressed needs of the businesses. Instead the information systems group perceived these future needs inspired by a variety of sources including: observations of competitor's use of IT, trade and industry press and IT vendors. Most of firms identified some of this type of IT investment and report some spectacular payoffs.

- e. The IT department identifies a basket of business process applications that will aggregate enough benefits to justify the infrastructure investment.

The IT department acts as a broker to identify emerging business needs by a number of businesses and provide infrastructure to enable systems to meet this need.

The majority of the firms used one of these rationales to justify a particular IT infrastructure project. Over the portfolio of infrastructure projects a particular firm used a number of these rationales.

Other firms adopted a consistent approach for all IT infrastructure investments. In one firm with a single business, the information systems department went to corporate headquarters for approval for each IT infrastructure projects. An IT case was made and usually justified in terms of reducing IT costs.

In a large bank the culture surrounding IT infrastructure was markedly different. All IT infrastructure investments were required to return a positive discounted cash flow. There was an attempt to quantify all tangible and semi-tangible benefits. The benefits for IT infrastructure were usually not direct business benefits (i.e. reduced branch labor) but rather reduced cost to provide a specified level of IT service. In this way the IT investment is evaluated in terms of information systems department costs. The value of the IT infrastructure to enable business units to build and use additional information systems to perform their business processes was not considered.

Firms with significant IT infrastructures in place usually tracked infrastructure usage such as telecommunications and mainframes over time. Plans for new IT infrastructure investments were based on projected usage of these systems. One corporate information systems function provided current usage and the projections to each business unit's information systems group each year for approval.

Finally, an approach was described where the threshold return for all IT investments was set each year. In 1991 the threshold was set at 20%. The IT department evaluated each proposed project. If the project was over the threshold, IT infrastructure was added until the project was just acceptable. The rationale was that

each project pay an "infrastructure tax" in accordance with its ability to pay. This approach appeared to be more politically motivated rather than an innovative justification strategy. IT infrastructure projects were difficult to cost justify and this "taxation" was a way to fund infrastructure.

A number of organizations identified that although most infrastructure investments were high, the marginal cost of increased capacity is relatively small. This was identified for most infrastructure investments including telecommunications, mainframe memory and storage. Given the uncertainty of predicting future needs, a common strategy is to install significantly more capacity (at small incremental cost) than is currently anticipated. This approach to IT infrastructure investment may help explain the current excess IT capacity in the installed base in services [Roach 1988]. It is also a factor in why most studies have been unable to demonstrate firm performance benefits of this type of IT investment [Kauffman & Weill 1990].

5. Towards a Model of the Role and Value of IT Infrastructure

A model of the role of IT infrastructure for a multi-business firm is presented in figure 2. A number of propositions and policy implications complete the paper.

The value of IT infrastructure is determined to a great extent by the way the firm views the role of IT infrastructure. The three different perspectives on the role of IT infrastructure: *independent*, *reactive* and *interdependent* imply quite different levels of investment, methods of justification and expected benefits.

Two types of IT infrastructure investment exist. The corporate information systems function provides firm-wide IT infrastructure of a specified reach and range. Firm-wide infrastructure provides

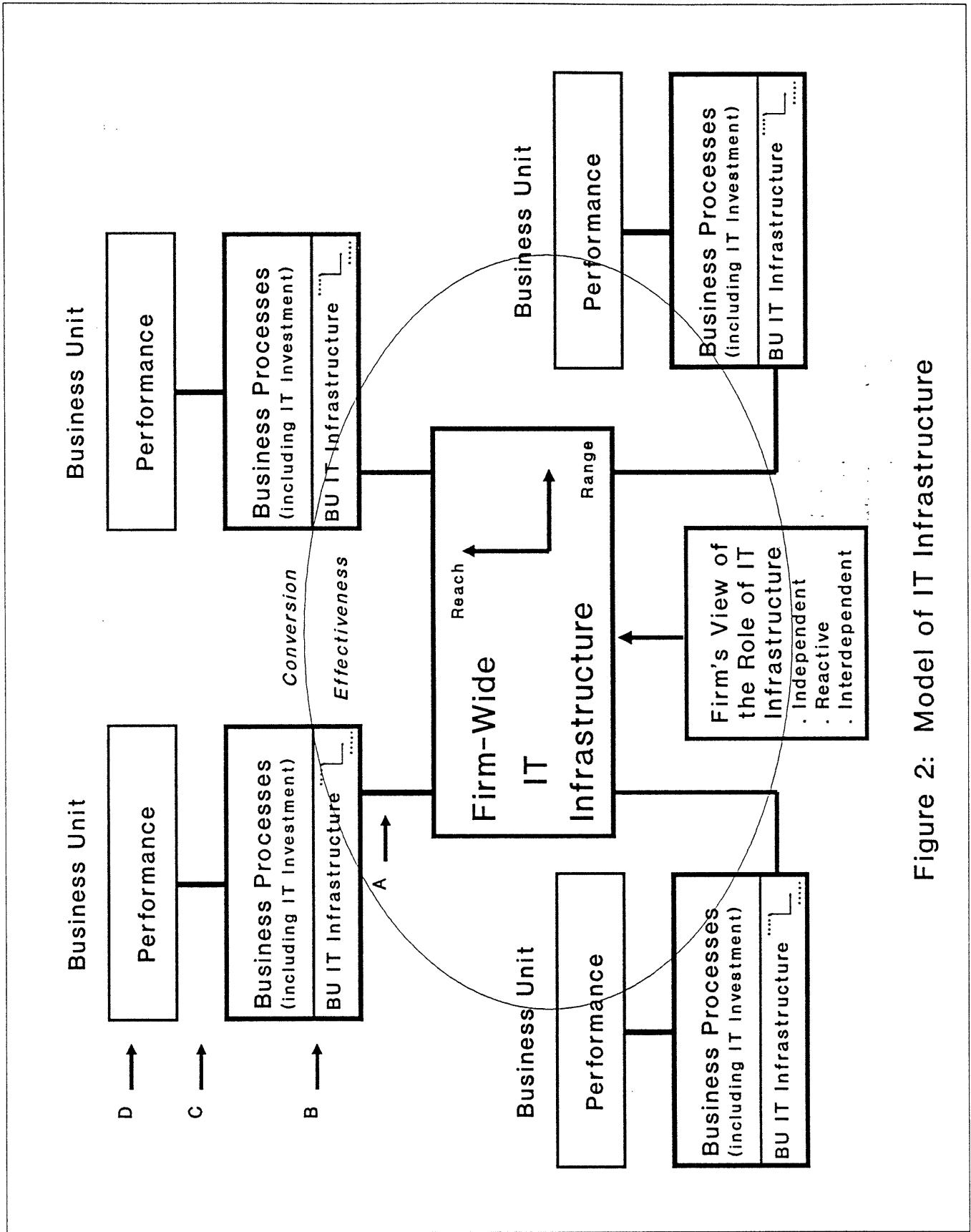


Figure 2: Model of IT Infrastructure

a number of benefits to the business units including, reduced IT costs, flexibility, and reducing the marginal cost of business unit IT investments to support the business processes.

Each business unit can build on the corporate IT infrastructure and have a more tailored local IT infrastructure of a specified reach and range. Examples exist of firms which have the business unit IT infrastructure provided by the corporate information systems function. There are also firms which have the business unit IT infrastructure provided by the information systems group within the business unit.

The IT investments in application systems to directly perform the business processes are then linked to the two levels of IT infrastructure. Changes in the business process and the associated systems can then be made often without changes to the IT infrastructure. The execution of the business processes in the market place drives the performance of the business unit. The business unit performance is influenced by many other factors including: industry structure, economic cycles and the strategic position of the business unit.

A hierarchy of value produced by IT infrastructure is proposed. The value of the IT infrastructure is produced at four places and therefore must be measured at four places in the firm (points A,B,C & D on Figure 2). The firm-wide IT infrastructure provides benefits (point A, for each of the business units, on Figure 2) which include flexibility, reduced cost for IT services, reduced time to market for new business unit products and services, and reduced marginal cost of business unit IT investments of both infrastructure and business process IT investment. In general, these benefits are expected to leverage and increase the return from the business units investments.

The local business unit infrastructures will provide incremental benefits (point B on Figure 2) to the business units. The

benefits will include flexibility, reducing the time to market for new business unit products and services and reduce the marginal cost of business unit IT investment directly related to the business processes.

Finally the actual business benefits will accrue to the business unit (points C & D). The benefits marked C are intermediate level benefits [Barua Kriebel & Mukhopadhyay 1991] resulting from more effective and efficient execution of the business processes. These benefits are operational level benefits such as capacity utilization, labor productivity, percent of on time delivery, defect rate, and customer satisfaction. These benefits are generally more robust than the next level (market D) which are measured by business unit performance indicators such as market share, return on assets, sales growth and return on sales. It is possible (as Barua, Kriebel & Mukhopadhyay found) that benefits will be measurable at point C but not at point D as the confounding effects of the other influences occur.

The useful measures and the relative size of the benefits at each of the four levels in the benefits hierarchy (A to D) will depend on the view the firm takes of IT infrastructure. For example, firms which view the role of infrastructure as *independent* will have the lowest levels of investment, will justify based purely on cost savings and expect benefits related to cost.

The ability of the firm to convert all their IT investments into productive outputs completes the model. Conversion effectiveness is the quality of the management and commitment to IT and moderates the relationship between IT investment and firm performance [Weill 1990]. Some firms have better conversion effectiveness and get more performance benefits from their IT investments. Conversion effectiveness is an aspect of the firm's organizational climate [Pritchard & Karasick 1973]. Weill [1990] showed that four factors, taken together, were representative of conversion effectiveness. These are:

- . top management commitment to IT
- . previous experience with IT
- . user satisfaction with systems
- . internal political turbulence of the firm. In a multi-business unit firm conversion effectiveness can vary considerably across the business units and corporate.

5.1 Propositions

A number of propositions and implications for management policy of IT infrastructure result from this model.

- P1. The total investment and the split between firm-wide and business unit infrastructure will be determined by the role (i.e. *independent*, *reactive* and *interdependent*) the organization identifies for IT infrastructure.

Policy Implications

- a. Clarifying the role for IT infrastructure and creating a corresponding shared organizational vision will focus scarce resources.
- b. Identifying the desired reach and range will determine the extent and thus the cost of the necessary IT infrastructure.
- c. The provision of an effective firm-wide IT infrastructure will be the major (and perhaps the only) role of the corporate information systems department.
- d. If the organization views the role of IT as *independent*, carefully consider outsourcing the firm-wide infrastructure. Viewing the role of infrastructure as outside the strategic context of the firm means that the only consideration in providing infrastructure is cost, at a negotiated service level. Outsourcing (or facilities management by another firm) enables reduced cost buy taking advantage of external specialist expertise and economies of scale.
- e. For firms that view IT infrastructure as *interdependent* the provision of an effective IT infrastructure can be a source of long-term competitive advantage.

P2. The measures and relative sizes of the benefits at the four points in the benefits hierarchy will depend on the role the organization identifies for IT infrastructure.

Policy Implication

Identify measures of benefits appropriate to the organization's view of the role of IT infrastructure at each of the four levels in the hierarchy and track over time.

P3. The clear payoff of public infrastructure and the similarities to IT infrastructure provide confidence that real benefits accrue from IT infrastructure.

Policy Implications

a. In a similar way to public infrastructure, IT infrastructure investment can be used to stimulate IT use and investment throughout the firm.

b. Establishing the payoff of IT infrastructure will be very difficult in individual organizations. Testimonials of the payoff of existing IT infrastructure are very effective in gaining support for further investment in firms that view the role IT infrastructure as *reactive* or *interdependent*.

c. Justifying infrastructure using traditional capital budgeting methods is recommended for firms who view IT infrastructure as *independent*.

P4. Firms with better conversion effectiveness will have larger benefits from IT infrastructure at all four levels of the hierarchy.

Policy Implication

It is possible to actively manage conversion effectiveness to increase the benefits from IT infrastructure investment. The human IT infrastructure is the critical component.

6. Conclusion

IT infrastructure is a vital part of the corporate IT portfolio. IT infrastructure is also probably the most difficult IT investment to justify in advance and then to measure the resulting impact. The model presented above illustrates, in part, why this is so. As the benefits are measured at points further distanced from the IT infrastructure investment (i.e moving from A to D) more dilution of the effect occurs. As the dilution increases, the influences of other factors increase in effect and confound the illustration of the impact of IT investment. This is a significantly more difficult problem for IT infrastructure than other IT investments due to the enabling nature of IT infrastructure. Unlike IT investment directly related to the business processes, the management objective of IT infrastructure is to provide flexibility and leverage latter IT investments.

IT infrastructure has a large momentum requiring, seemingly, ever increasing resources. The cost of significant changes to infrastructure are high and well beyond the cost of the purchases and the associated information systems personnel. The political and organizational costs are often the major hurdles to changing a firm's IT infrastructure and bias towards the continuation of the status quo. Outsourcing is seen by some senior managers as a way to off-load these ever increasing costs of infrastructure. Outsourcing is an attractive solution to firms that view the role of infrastructure as *independent* of the strategic context.

For firms who view the role of infrastructure as *reactive* or *interdependent*, however, IT infrastructure planning and management must to be admitted into the mainstream of corporate management.

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