Mari Nyrhinen

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ABSTRACT

Studies related to IT infrastructure emphasize its changing and differing roles, functions and forms. This study reviews the literature related to IT infrastructure and combines its different elements into one holistic model. The model is further elaborated by using the concepts of structure, properties and processes. The model will help academics to find essential information about IT infrastructure and help practitioners to understand its importance and the possibilities related to leveraging it. After detailed analysis of the model, the study suggests that though topical literature presents a widely held common understanding of the elements existing within IT infrastructure, more research is needed to develop and unify definitions of old and new concepts related to the properties and processes of IT infrastructure.

Keywords: IT infrastructure

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Table of Contents

1. Introduction

The importance of Information Technology (IT) infrastructure is recognized more and more within companies and corporations. In addition to the increasing interest shown for IT infrastructure by practitioners, the academic literature abounds with research and studies related to the topic. The sooner companies realize the importance of building and leveraging IT infrastructure, the better will be the value and higher the return they can capitalize on. But what is IT infrastructure, actually? *Firm-wide centrally coordinated IT infrastructure* consists of technology components (such as communication technology and data) which individuals with technical and managerial competence use to produce standard and shared services. These services are then provided for shared and standard, firm-wide and business-specific applications, at the service levels required, according to standards defined in the IT architecture. It is understood, of course, that the flexibility of IT infrastructure and the securing of compatibility within and between the IT infrastructures of business units, industry and the public must also be arranged. This study, however, is delimited to firm-wide IT infrastructure.

IT infrastructure is a complex entity, which explains over 50% of the IT budget of a typical organization, and the percentage is growing at a rate of 11% every year (Broadbent and Weill, 1997). However, defining the actual monetary value produced by IT infrastructure is difficult, even though its importance can be described in many ways, as a source of competitive advantage, (Broadbent and Weill et al., 1996), for example. One field of interest is the description of the properties of infrastructure as an explanation of its worth. Byrd (2001) and Byrd and Turner (2001), for example, explain how the flexibility of IT infrastructure influences the competitive advantage of a company.

Despite the fact that IT infrastructure is ever more widely described and presented in an increasing number of academic articles, a more coherent and consistent view is still needed. Terms describing the properties of IT infrastructure, for example, are used in a number of diverse and often inconsistent ways in current literature, which negates much of the seeming unity of concepts used. The objective of this paper is to offer a new, comprehensive model which combines the elements of IT infrastructure explained in different ways and emphasized to different degrees in previous studies.

From a practical perspective, the results of this study are valuable as a tool for acquiring a comprehensive view of IT infrastructure – its elements, the related properties, the utilization of these properties in practice, and the processes through which IT infrastructure brings value to companies. The research and its subsequent findings are important for science for two reasons. Firstly, the model combines the elements of IT infrastructure found in current literature. Secondly, it further develops the IT infrastructure model presented by McKay and Brockway (1989). This study also lists the properties of IT infrastructure presented in the literature reviewed, and classifies their use in various studies according to the structural elements of IT infrastructure to which they are related. The study further includes descriptions of the properties as used in the various studies, revealing the wide range of nuances of meaning which may be referred to by different researchers using the same terms. Methods of evaluating the value of IT infrastructure, and issues related to this problem area are dealt with in the third section of the second chapter.

Finally, the study describes the deficiency of the research related to IT infrastructure properties and processes, which calls for further studies to focus on the issues of property and process related to IT infrastructure.

The articles for this review have been selected from ProQuest, which is the electronic database of the Helsinki School of Electronics library. The search word was 'IT infrastructure', and the search was limited to scholarly journals. The search produced a result of 85 articles. Skimming through the articles and their references helped to identify the ones most valid and relevant to IT infrastructure. These were selected to support the IT infrastructure model presented. This model will be described in chapter 2, presenting the definition and model of IT infrastructure, which is further elaborated in the sections - structure, properties and processes of IT infrastructure. In this paper *Structures* incorporates the various elements that make up IT infrastructure. *Properties*, on the other hand, explains concepts used to describe IT infrastructure. Finally, *Processes* describes how IT infrastructure is valued within companies. It is also important to note that IT infrastructure can be evaluated from two distinctive perspectives: the development of IT infrastructure, or the use of IT infrastructure. This study focuses on the latter view, the use of IT infrastructure. Chapter 3 draws together the conclusions.

2. IT infrastructure

IT infrastructure, as a separate element, is now more widely recognized than before and many justifications are used to describe its importance. On the basis of an analysis and synthesis of the definitions and purposes of IT infrastructure found in the literature review, IT infrastructure is seen to serve the following purposes:

1) *forms a (technical and human) basis for business and business applications*
(Barney, 1991; Davenport and Linder, 1994; Duncan, 1995a; Rockart and Earl et al., 1996; Broadbent and Weill et al., 1996; Grover and Teng et al., 1998; Hanseth and Braa, 1998; Sääksjärvi, 2000; Byrd, 2001; Kayworth and Chatterjee et al., 2001; Xia and King, 2002),

2) *holds, routes, assembles and shares information, satisfying business and management needs for reducing costs and increasing efficiency* (Earl, 1989; Barney, 1991; Davenport and Linder, 1994; Dixon and Arnold et al., 1994; Duncan, 1995a; Rockart and Earl et al., 1996; Broadbent and Weill et al., 1996; Grover and Teng et al., 1998; Sääksjärvi, 2000; Byrd and Turner, 2000; Byrd, 2001; Kayworth and Chatterjee et al., 2001; Xia and King, 2002),

3) *enables the planning and modifications of business processes, supports the emergence of new organizational forms, improves connectivity among interest groups and helps globalization*
(Clemons and Row et al., 1989; Neo, 1991; Davidow and Malone, 1992; Grover and Teng et al., 1993; Miller and Clemons et al., 1993; Wastell and White et al., 1994; Caron and Jarvenpaa et al., 1994; Furey and Diorio, 1994; Porter, 1996; Rockart and Earl et al., 1996; Broadbent and Weill et al., 1996; Davidson and Movizzo, 1996; Grover and Teng et al., 1998; Sääksjärvi, 2000; Xia and King, 2002; Evaristo and Munkvold, 2002), and

4) *fosters the attainment of sustainable competitive advantage as a core competence of the firm, and, as a flexible platform, enables rapid new implementation of innovations and cost effective modifications of existing applications*
(Keen, 1991; Barney, 1991; Boynton and Victor et al., 1993; Davenport and Linder, 1994; Duncan, 1995a; McKenney 1995; Broadbent and Weill et al., 1996; Sääksjärvi, 2000; Byrd, 2001; Kayworth and Chatterjee et al., 2001).

As we can see, IT infrastructure plays an important role in the operations of every firm. In the following sections IT infrastructure is further elaborated by using the concepts structure, properties and processes.

2.1. Structure

McKay and Brockway (1989) were among the first to describe IT infrastructure. They define IT infrastructure as the enabling foundation of shared information technology capabilities upon which business depends. They present elements of IT infrastructure in their three-layer model, which is described in Figure 1. On the bottom layer (layer 1) are the *Information Technology Components*, which are commodities readily available off the shelf, such as computers, printers, routers, database software and operating systems. The middle layer (layer 2) consists of *Human IT technology*, which includes the knowledge, skills, policies, standards and experience required for binding the technology components to the necessary services referred to in layer 3. This top layer, called *Shared Information Technology Services*, includes services which are stable over time, such as management of shared customer databases.

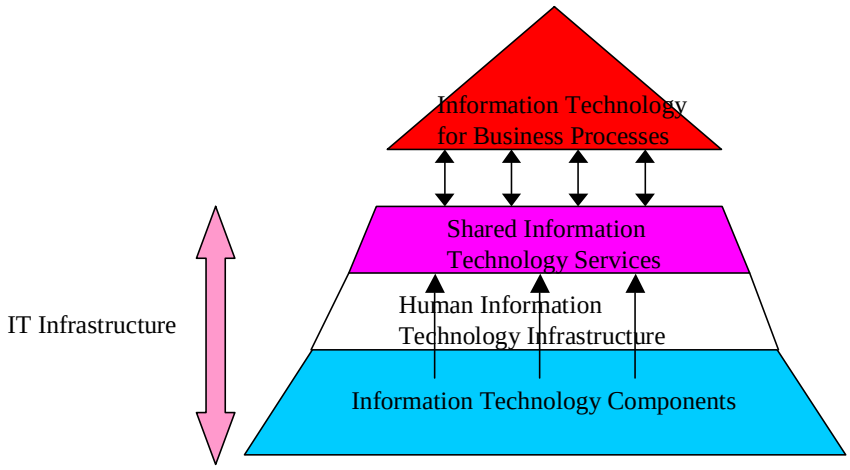

Figure 1: Elements of IT infrastructure presented by McKay and Brockway (1989)

Since McKay and Brockway (1989), many other researchers have added new elements and concepts to define and describe IT infrastructure. This study assembles them into one holistic model presented in Figure 2.

This study defines firm-wide IT infrastructure as follows:

Firm-wide centrally coordinated IT infrastructure consists of technology components (such as communication technology and data) which individuals with technical and managerial competence use to produce standard and shared services. These services are then provided for shared and standard, firm-wide and business-specific applications, at the service levels required, according to standards defined in the IT architecture. It is understood, of course, that the flexibility of IT infrastructure and the securing of compatibility within and between the IT infrastructures of business units, industry and the public must also be arranged. This study, however, is delimited to firm-wide IT infrastructure.

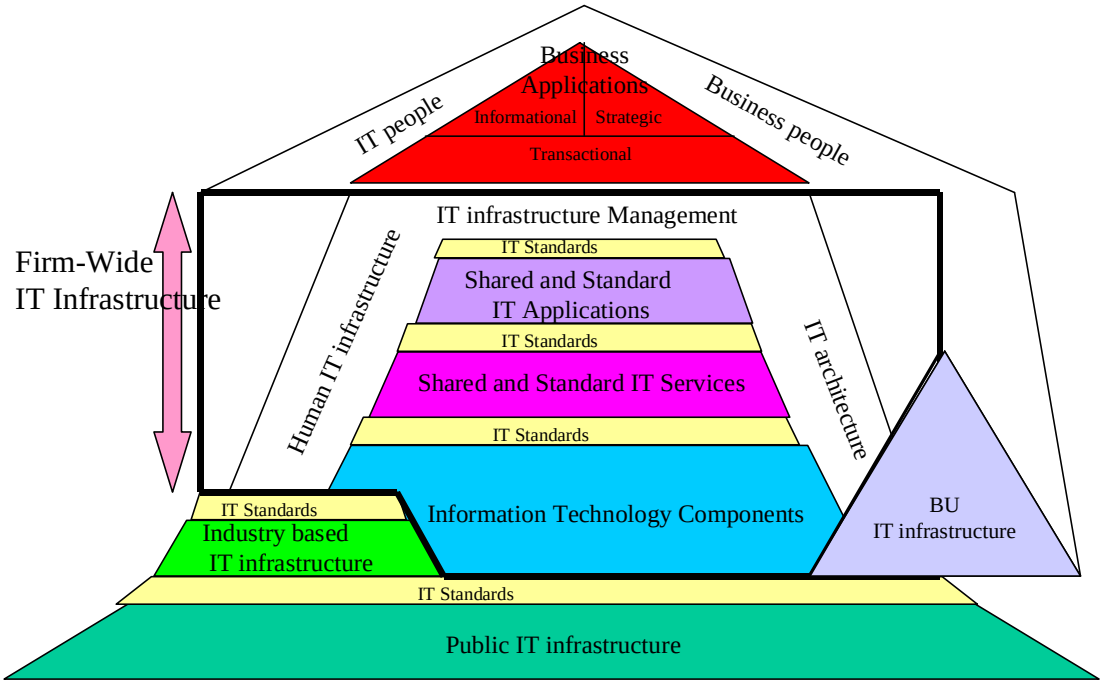

Figure 2: IT infrastructure

This model of IT infrastructure is adapted from McKay and Brockway (1989). The picture is further modified and complemented for the needs and requirements of this study. As a basis for firm-wide IT infrastructure, the technology components are connected to industry based and public infrastructures through the IT standards defined by the industry authorities and the public IT environment. Business units may have IT infrastructures of their own, which are connected to firm-wide IT infrastructure through the standards defined in firm-wide IT architecture. IT infrastructures of business units can be connected directly to public or industry based infrastructures. The firm-wide technology components are standardized technology components, which use certain standards (e.g. TCP/IP) and which are utilized to provide shared and standard IT services, mostly by technically skilled IT people. In addition to technical IT services, also human services, such as project management, may be provided as part of IT infrastructure services. These IT services are provided for the shared and standard IT application layer of IT infrastructure. In addition, the IT infrastructure services also perform tasks directly for business applications. Human IT infrastructure, with technical and managerial competence, has an important role in further developing and maintaining IT infrastructure as an entity serving business needs. Figure 2 will be reviewed and explained in greater detail in connection with a discussion of how other scholars have contributed to the area of IT infrastructure. While the basic structure (as presented by McKay and Brockway, 1989) remains, the applications layer is added to the basic model, and the human IT infrastructure and standards elements are emphasized. Finally, the portfolio concept introduced by Weill and Broadbent (1998) is described as a tool for connecting IT infrastructure to the entity of IT.

2.1.1. Shared and Standard IT Applications Added

As mentioned earlier, McKay and Brockway (1989) describe IT infrastructure using a 3-layer model. Weill and Broadbent (1998) take that structure as their basis and further complement the model by adding a fourth layer on top of Shared Information Technology Services. This they name S*hared and Standard IT Applications*. The layer includes the shared and standard firm-wide applications which remain unchangeable for long periods of time, for such functions as accounting, budgeting and human resource management. This layer is also described in Figure 2. What is included in the IT infrastructure depends on the organization. For example, some firms may include accounting in their IT infrastructure, some firms don't. Every organization must be aware of what is included, what could be included and what it is reasonable to include in their IT infrastructure. According to Duncan (1995a), data and software components are subsumed into IT infrastructure as they become technically independent – standardized, shareable, and reusable in a variety of present and future business implementations. Technical independence is at the same time relative.

After adding this fourth layer, the IT infrastructure model can now be called the 4-layer model. Broadbent and Weill et al. (1996) define IT infrastructure as the base foundation of budgeted IT capability (both technical and human), shared throughout the firm in the form of reliable services and shared applications, which are usually centrally coordinated.

2.1.2. Human IT Infrastructure with Management and IT Architecture Emphasized

The first descriptions of IT infrastructure, in the late 1980s, focus mostly on the technology components of IT infrastructure (e.g. Earl, 1989; Turnbull, 1991). Despite the fact that the human component of IT infrastructure was recognized before (McKay and Brockway, 1989), it was not until the mid-1990s that it was actually emphasized. Lee and Trauth et al. (1995) describe certain types of knowledge and skills required for managing technology, business functions, technical specialties and interpersonal communication. Broadbent and Weill et al. (1996) emphasize the necessity of the human component of IT infrastructure in providing the planning, design, construction and operations capability needed for viable IT infrastructure, and ways in which human IT infrastructure binds the IT components into a reliable set of shared IT infrastructure services. Duncan (1995a) describes IT infrastructure on two levels. The first level consists of tangible resources, such as hardware, network, telecommunications technology and operating systems. This first level corresponds with layer 1 presented by McKay and Brockway (1989) and to the technology components presented in Figure 2. Duncan (1995a) describes the management and planning factors of IT infrastructure in her second layer of IT infrastructure. She does this by separating the concepts alignment, architecture and skills. *Skills* and knowledge belong to individuals having not only technical competence, but also competence related to management, business, and other qualities needed in organization. These individuals with a variety of competences are an essential part of IT infrastructure. They build and are prepared for the needs and requirements of the present, and the future and unknown needs of IT infrastructure. They do this through *alignment*, which means that IT plans, including IT infrastructure, are in line with

business plans. This is ensured by continual communication with senior business managers and possible third parties, such as vendors.

This course of action is described in *IT architecture*, which is a part of IT strategy. Architecture provides a model for continuous design, building and analyzing of the IT infrastructure. The way Duncan (1995a) describes her second layer of IT infrastructure corresponds with layer 2, Human IT infrastructure in the model by Mckay and Brockway (1989), and with Human IT infrastructure and IT architecture in Figure 2. In Figure 2 human IT infrastructure is divided into *managerial and technical competence* to emphasize how both skills are important in connection with other kinds of business and organizational skills needed in a company to develop and maintain IT infrastructure as an entity. In addition, there is an increased need to manage IT risks and vulnerabilities. The temporal stability of many IT infrastructure services has shortened dramatically due to the changed nature of IT risk management – such as protection against viruses and service attacks. The human component of IT infrastructure communicates with business people and other IT personnel who are not directly working with IT infrastructure. The other IT personnel serve the actual business further by building applications for specific business needs and maintaining the IT infrastructures of business units, for example. Today employees are not the only ones to use the IT infrastructure of the firm. It is increasingly used also by customers, vendor, and other stakeholders outside the premises of an enterprise.

The model for this action is formulated in IT architecture. IT architecture is depicted in Figure 2 as a separate element of human IT infrastructure in order to emphasize that the building and maintaining of IT infrastructure should be systematically organized and directed. The quality of IT infrastructure service for business needs depends on how senior management and the Chief Information Officer (CIO) of the company have succeeded in expressing their needs to IT strategy and IT architecture personnel, and the skill of the human IT infrastructure in providing the required IT infrastructure services. Duncan (1995a) describes IT infrastructure as a set of shared tangible IT resources (such as hardware, network, operating systems) which provide a foundation to enable present and future business applications.

2.1.3. IT Standards Emphasized

Kayworth and Chatterjee et al. (2001) view IT infrastructure mainly through services. They present a conceptual model consisting of 4 dimensions. The main dimension is *shared information technology services*, which consists of three further dimensions. This shared services dimension is comparable to layer 3 in the layer model presented by McKay and Brockway (1989) and the shared and standard IT services layer in Figure 2. Three other dimensions are combined as one, with IT standards in the middle, in interdependence with physical and intellectual IT assets at its sides. *Physical IT assets* is comparable to layer 1 and *Intellectual IT assets* to layer 2 of the layer model presented by McKay and Brockway (1989). While McKay and Brockway (1989) and Broadbent and Weill et al. (1996) include IT standards in the actions of the human component of IT infrastructure without further attention (layer 2), and Duncan (1995a) deals with these as a part of architecture, Kayworth and Chatterjee et al. (2001) place greater emphasis on *IT standards*. They distinguish standards from the human component of IT infrastructure (Intellectual IT assets), because they see IT standards as a routine part of organizational memory, whereas intellectual assets may be more transient and less routine. According to Kayworth and Chatterjee et al. (2001),

IT standards dictate how IT assets are to be acquired, managed, and utilized within the organization. Standards act as the glue that links the use of physical and intellectual IT assets. Shared services are thus a result of the blending of physical and intellectual assets according to the rules and guidelines prescribed by standards. In Figure 2 the standards are emphasized by placing them in the middle and around every layer to describe, and to some extent even dictate the standard procedures of people and how they interface with these services. Standards secure the compatibility of firm-wide IT infrastructure with the IT infrastructures of public (e.g. internet, telecommunication networks), industry (e.g. EDI networks, airline reservation systems), and business units. So in Figure 2, the standards can be further described by Keen's (1995) definition. *Standards* are agreements on formats, procedures, and interfaces that permit designers of hardware, software, databases, and telecommunications facilities to develop products and systems independent of one another with the assurance that they will be compatible with any other product or system that adheres to the same standards. Kayworth and Chatterjee et al. (2001) define IT infrastructure as organizational resources typically coordinated by some form of central Information System (IS) organization and shared across organizational units. The definition of IT infrastructure made by Rockart and Earl et al. (1996) further helps users to understand what IT infrastructure really is. They define *IT infrastructure* as telecommunication, computers, software, and data that is integrated and interconnected so that all types of information can be effortlessly routed from the user's viewpoint, through the network, to redesigned processes.

2.1.4. IT Portfolio

Usually, IT infrastructure is seen as a part of Information Technology (IT). Weill and Broadbent (1998) explain how IT infrastructure fits into the totality of IT. They divide IT into four elements, each of which describes a management objective. They call this entity the *IT portfolio*. At the bottom of the portfolio is *IT infrastructure*, the purpose of which is dealt with in greater depth in the next section. IT infrastructure is the foundation for other parts of the portfolio. Above IT infrastructure is a *transactional element*, referring to transactional applications used for cutting transaction costs by increasing volume or decreasing personnel. This can be achieved by investing in a new order processing system, for example. Above the transactional element are the informational and strategic elements. The objective of the *informational element* is to provide information better designed for the uses for which it is needed, eg. management or marketing. Typical examples of investments related to the information element are data warehouse projects. If management invests in the *strategic element* of the portfolio, the aim is to gain competitive advantage or increased sales.

The IT portfolio is like a stock portfolio, where risk and returns must be in balance. For example, if investments are made in the transactional element, the return is fairly certain. But if investments are made in the strategic element, 50% of those usually fail (Weill and Broadbent, 1998). It is important for management to understand nature of IT infrastructure, its role in the company and its possible utilization for business purposes. Every company must invest enough in IT infrastructure to ensure its adequacy as a basis for the other parts of the portfolio, and prevent it from becoming a bottleneck for other IT investments. Investments in IT infrastructure involve moderate risks, due to long cycle of returns, and business and technical uncertainty meanwhile (Weill and Broadbent, 1998).

2.2. Properties

There is no single best or correct form of IT infrastructure, on the contrary every organization must build and maintain IT infrastructure to correspond to its own needs. IT infrastructure requirements are often presented in the form of various properties. These properties are also used to measure essential qualities of IT infrastructure and to evaluate how it can fulfill business requirements. The most widely used properties are probably flexibility, capability and effectiveness, which in turn include many other minor properties, such as the widely used concepts of reach and range. *Reach* refers to the locations and people which the IT infrastructure is capable of connecting, and *range* refers to functionality, in terms of the business activities that can be completed and shared automatically and seamlessly across every level of reach (Keen, 1991). Reach and range describe the business scope of the firm's infrastructure - what types of messages can be sent, and transactions processed between employees, suppliers, and customers (Weill and Broadbent, 1998). The various properties are explained below and drawn together into table 1. In table 1 this study also connects each property to the various structural elements of IT infrastructure presented in Figure 2.

2.2.1. Flexibility

Flexibility of IT infrastructure describes the degree to which its resources are *sharable* and *reusable* and how rapidly and effectively the IT organization is able to respond to emergent needs or opportunities (Duncan, 1995a). Duncan (1995a) describes the sharable aspect of flexibility using technical concepts such as connectivity, compatibility and modularity. *Connectivity* is the ability of any technology component to attach to any of the other components inside and outside the organizational environment (Byrd, 2001). Connectivity is consistent with the concept of reach. *Compatibility* is the ability to share any type of information across any technology components (Byrd, 2001). Compatibility is consistent with the concept of range. *Modularity* is the ability to add, modify, and remove any software or hardware components of IT infrastructure with ease, and with no major overall effect (Byrd, 2001).

Byrd (2001) defines *flexibility* as the ability of the infrastructure to support a wide variety of hardware, software, and other technologies, which can be easily diffused into the overall technological platform to distribute any type of information – data, text, voice, images, video – to anywhere inside an organization and beyond, and to support design, development, and implementation for a heterogeneity of business applications. According to Byrd (2000) IT infrastructure flexibility can be measured with three factors, namely integration, modularity and IT personnel flexibility. *Integration* is a combination of compatibility and connectivity. *Modularity* is a combination of application functionality and database transparency. Application functionality is the ability to add, modify, and remove any software applications of the infrastructure with ease and with no major overall effect. Data transparency is defined as the free retrieval and flow of data between authorized personnel in an organization or between organizations, regardless of location. *IT personnel flexibility* includes the abundance of skills, competence and knowledge of technical, managerial and business issues expected from IT personnel. According to Byrd and Turner (2001) IT personnel flexibility is a combination of technical, boundary, functional and technology management skills. *Technical skills* are a set of measures of technical capabilities such as

programming, understanding software development processes, and knowledge of operating systems. *Boundary skills* are the knowledge and skills outside of training or original competencies. *Functional skills* are the ability of IT personnel to understand the business processes they support and to apply technical solutions. *Technology management* describes the organization's ability to support business strategies in the most effective way (Byrd and Turner, 2001).

In table 1 IT personnel flexibility, together with all other organizational skills, is assigned to either Human IT Infrastructure, generally emphasizing more technical skills, or to IT Infrastructure Management, emphasizing managerial skills. The study by Byrd and Turner (2001) is one of the rare studies where flexibility is applied. They provide evidence to show that IT personnel flexibility is the strongest IT infrastructural factor affecting the competitive advantage of the firm. Xia and King (2002) have used flexibility in a different way - as an aspect of property capability. They measure flexibility of technological components with the terms compatibility (presented by Duncan, 1995a), adaptability and expandability. However, they not explain or define adaptability and expandability in any way. They deal with IT personnel flexibility as an integral part of IS management competence, incorporating within it the technical and managerial skills and general flexibility of the IS staff in response to business needs and requirements.

2.2.2. Capability

Broadbent and Weill et al. (1996) use IT infrastructure capability to describe services. *Capability* is a combination of functionality and connectivity. *Functionality* is defined by the IT infrastructure services offered firm-wide. *Connectivity* is defined by the reach and range of the IT infrastructure. Services, reach and range are measures of IT infrastructure capability. Both the concepts of capability and flexibility are measured by reach and range, but the third measurement for flexibility is modularity, and for capability it is functionality.

The Services concept is a part of IT infrastructure and can be directed at layer 3 of the layer model. However, Weill and Broadbent (1998) have used it to describe how business managers understand and value IT infrastructure. By evaluating IT infrastructure through services, business managers resemble the consumers who buy those services. They are able to compare the price and extent of services provided not only internally, but also externally. Weill and Broadbent (1998) distinguish between the core and additional services of IT infrastructure. *Core* services (such as the management of firm-wide communication network services) are found in all firms, but *additional* services (such as the performing of IS project management) were provided in varying degrees. Weill and Broadbent (1998) also used depth of service to divide the service level into *selective* and *extensive* levels. For example, the service 'Provide multimedia operations and development' at a selective service level is very limited, as is also 'provision of video conferencing facilities'. On the other hand, the same service at the extensive level could be, for example, 'development and management of multimedia applications to support communication across countries'. Similar services can be grouped into service clusters. Weill and Broadbent (1998) have probably used the capability concept most widely. For example, they (Broadbent and Weill et al., 1996) define how increased capability is needed in companies where products change quickly. These companies attempt to capture and identify synergies across business units by integrating information and emphasizing long-term strategy.

Xia and King (2002) study the ways in which organizational factors influence IT infrastructure capabilities and investment requirements. Their study indicates that the external environment is not directly related to IT infrastructure capabilities. This is perhaps because requirements from the environment come through strategy alignment which, combined with business synergies, is the most significant predictor of IT infrastructure capability. An interesting point in the study is the measures used for capability. The measures are reach (Keen, 1991), and range (Keen, 1991), but instead of functionality, the other measures are flexibility (as defined in the paragraph above on flexibility), IS standards and procedures, and IS management competence. This is one of the rare studies where the evaluation of standards and procedures of IT infrastructure is included. The measurements for standards and procedures have been adapted from Duncan (1995b).

2.2.3. Effectiveness

In the literature, the word effectiveness is used in various ways. Effectiveness evaluates success more from the user perspective, because it focuses on the results provided by human IT infrastructure. If different organizations invest in exactly the same technology components, the provided services and their quality will differ. This is because human IT infrastructure, with differing skills, provides these services. The success achieved in implementing and managing the IT infrastructure depends on the competence of humans. *Effectiveness* is used to describe the results which human IT infrastructure provides from IT technology components (Weill, 1992). The results can be seen at the standard and shared services and applications levels (layer 3 and 4). Effectiveness can be seen as how other people in the company perceive and value the provided services. Effectiveness is measured by the knowledge, skills and experience of human IT infrastructure, and the quality of the development and implementation of IT applications and technical IT infrastructure (Weill, 1992). In table 1, effectiveness within the required skills is connected to Human IT Infrastructure and to IT Infrastructure Management.

The traditional way of evaluating IT success is to do it from the user perspective. This is more difficult in the case of IT infrastructure, because IT infrastructure serves its users mostly through applications. DeLone and McLean (1992, 2002) evaluate IT investments in general by checking how individuals assess IT services. They measure IT investments through information quality, system quality and service quality, which influence the ways users use the systems, and user satisfaction, which in turn combine to form net benefits (total value) for *IS success*. DeLone's and McLean's measurement of IS success is geared toward applications, but it should also indicate how well IT infrastructure supports those applications. Weill's (1992) definition of IT infrastructure effectiveness is close to the description of IS success by DeLone and McClean (1992, 2002). Effectiveness focuses on the human component of IT infrastructure, including management, where the emphasis is on the 'goodness and fastness' of individuals, whereas the focus in IS success is on various quality measures made for users. But together these measures complement each other.

Sääksjärvi (2000) uses the concept of IS effectiveness in his study. Effectiveness is used to measure factors such as how IT contributes to strategic company goals, produces relevant information and improves productivity. According to the results of this study, the ways in which IT infrastructure (roles) is used and their degree of integration contribute significantly to IS effectiveness.

The properties in table 1 together with the various concepts describe or measure certain IT infrastructure elements in a more detailed and specific way. IT infrastructure is mainly described by flexibility, capability, and effectiveness. But if we make a careful study of the elements of IT infrastructure, we can see that reach and range play an important role in describing technology (layer 1) and IT services (layer 3). Human IT infrastructure and IT infrastructure management are described by a variety of skills, experience and knowledge, which are required of individuals. Table 1 suggests that it is not possible to unambiguously connect the used properties to individual elements of IT infrastructure, or to relate other concepts used to an individual property. This study does not evaluate IT standards and architecture, because they are essentially instructions and procedures. How well instructions and procedures are established and work depends on how well the services are provided.

Element of IT infrastructure	Property	Concepts, which are used to describe property
Technology Components	Flexibility Duncan, (1995a)	Sharable • Reach (Keen, 1991) = Connectivity (Duncan, 1995a) • Range (Keen, 1991) = Compatibility (Duncan, 1995a) • Modularity Reusable
	Flexibility Byrd, (2000)	Integration • Connectivity (Duncan, 1995a) • Compatibility (Duncan, 1995a) Modularity • Application functionality • Data transparency
	Flexibility Xia and King (2002)	Compatibility (Duncan, 1995a) Adaptability (Xia and King, 2002) Expandability (Xia and King, 2002)
Human IT Infrastructure	Flexibility Byrd and Turner (2001)	IT personnel flexibility • Technical, boundary and functional skills
	Effectiveness Weill, 1992	• Knowledge • Skills • Experience
IT Infrastructure Management	Flexibility Byrd and Turner (2001)	IT personnel flexibility • Technology management, boundary and functional skills
	Flexibility Xia and King (2002)	IS Management competence • Technical skills of IS staff, managerial skills, flexibility of IS function
	Effectiveness Weill, 1992	• Knowledge • Skills • Experience
Shared and Standard IT Services	Capability (Boradbent and Weill et al., 1996)	Functionality • IT infrastructure services With service level • Selective • Extensive Connectivity • Reach (Keen, 1991) • Range (Keen, 1991)
Shared and Standard IT Applications	Flexibility (Byrd, 2000)	Modularity (Byrd, 2000)
IT Architecture		-
IT Standards		-

Table 1: Elements and properties of IT infrastructure

2.3. Processes

2.3.1. Value of IT Infrastructure

The value of IT infrastructure is very difficult to define, because IT infrastructure is a complex set of technological resources developed over time, and thus the value of IT infrastructure remains largely in the realms of conjecture (Duncan, 1995a). According to Broadbent and Weill (1997), over 50% of total IT investments are directed into IT infrastructure, and these investments have increased at about 11 percent annually. If we think of public IT infrastructure, and more specifically the Internet, it seems impossible to estimate the added value it has produced for various companies and individuals. Grover and Teng et al. (1998) point out that firm-wide IT infrastructure investments are fourth among the six most important IT investments.

According to Weill and Broadbent (1998) the business value of a firm is created through IT infrastructure. How business value is defined depends largely on the firm's strategic context and objectives. Weill and Broadbent (1998) use a 4-level hierarchy to define value from IT infrastructure. The first level focuses on operational measures, such as time and cost of new applications, and the highest and most important level is the financial performance of the firm, which is measured by e.g return of assets. Individuals in human IT infrastructure create value by using their skills and by applying technology components to provide services. The speed and effectiveness of these services creates the value for IT infrastructure.

Kayworth and Chatterjee et al. (2001) describe the potential of IT infrastructure for creating value by responsiveness (ability of firms to quickly adapt products and services in response to changing business conditions), innovativeness (ability of the firm to successfully innovate) and economies of scope (ability to reduce the cost and time in competition with other firms). According to Byrd and Turner (2000) the value of IT infrastructure is determined by single properties, of which one of the most important is flexibility. Broadbent and Weill et al. (1996) prefer to use the property of capability instead of flexibility, which Duncan (1995a), and Byrd (2001) with Turner (Byrd and Turner 2000, 2001) prefer. As stated earlier, flexibility, capability and effectiveness consist of many minor aspects, which together further describe IT infrastructure.

Dos Santos (1991) attempts to measure IT investments in general by using Net Present Value (NPV), as presented by finance academics. The problem is, however, that IT infrastructure does not produce immediate value, instead it enables forthcoming IT projects to be implemented faster. So the IT infrastructure value comes through savings achieved by other projects, and through the support provided by IT infrastructure for both the strategic goals of the firm and its day-to-day business. The strategic value of IT infrastructure can be seen as the support it provides specifically for innovations. According to Dos Santos and Peffers et al. (1993), innovative general IT investments have an influence on the market value of the firm. If IT infrastructure can be shown to provide support for IT innovations, at least part of the value of IT infrastructure can be seen in the stock price of the company. Weill and Broadbent (1998) seek to include in their evaluation the value anticipated from future projects by suggesting that traditional Discounted Cash Flow (DCF) techniques such as NPV be complemented by value analysis. Value analysis, also called subjective analysis, relies on the expertise of consultants and the authority of senior management. They make the best possible estimates, which are used for evaluation of future projects.

As we can see, there are many ways of evaluating IT infrastructure – by the money spent on IT infrastructure, by the speed and effectiveness of the services provided, by value analyses etc. One other way to evaluate IT infrastructure is to show that it is a core competence of the firm, or a sustainer of competitive advantage. The firm is said to have a *sustained competitive advantage* when it is implementing a value-creating strategy not simultaneously being implemented by any current or potential competitors, and when these other firms are unable to duplicate the benefits of this strategy (Barney, 1991).According to Quinn and Hilmer (1994) *core competencies* are those activities which offer long-term competitive advantage and must thus be rigidly controlled and protected. But when can it be said that IT infrastructure is the core competence? One way to evaluate this is through roles or views.

2.3.2. Roles and Views

Roles and views are used to describe the value and purpose of IT infrastructure in the company. How IT infrastructure is valued depends on the firm's strategic and environmental context. Weill and Broadbent (1998) suggest four views on valuing and controlling IT infrastructure in firms. According to

1) the *none* view management objectives are not related to IT infrastructure. IT infrastructure is just built for some reason to support something. There is no firm-wide IT infrastructure. In
2) the *utility* view, the objectives of IT infrastructure are cost savings, and investments in IT infrastructure are made only if cost savings can be achieved. In
3) the *dependence* view the aim is to achieve business benefits. IT infrastructure capability is driven by current business strategy. Finally in
4) the *enabling* view the aim is to concentrate on current and future firm flexibility. IT infrastructure is a core competence of the firm and extensive capability is provided to increase strategic options.

Sääksjärvi (2000) deals with the meaning of IT infrastructure in firms through roles. In the

1) *common IS Core* role the mission of IT infrastructure is to improve connectivity among suppliers, clients and partner companies, and to offer a compatible common core for business applications. In the
2) *strateby enabler* role the mission of IT infrastructure is to support and enable implementation of corporate and business strategies. And in the
3) *flexible platform* role the mission is to offer a flexible basis for business applications while reducing cost.

Both Weill and Broadbent (1998) and Sääksjärvi (2000) point out, that the different views or roles of IT infrastructure are visible in company actions in different ways. For example according to Weill and Boradbent (1998), in the 'none view' IT infrastructure is used only within business units. Small firms often hold the none view. In the utility view, IT infrastructure is used between business units mainly to perform simple transactions. Traditional manufacturing industry usually holds a utility view. In the dependent view IT infrastructure is used between business units, and also to

perform some complex transactions with some customers. In order to utilize their IT infrastructure better, companies today aim more and more often toward a dependent view. If IT infrastructure is a core competence of company, it is in a central role when doing business. In this enabling view, IT infrastructure is used within and between business units to perform complex transactions with all customers.

As we can see, Weill and Broadbent (1998) connect capability to their views of IT infrastructure. In the similar way Sääksjärvi (2000) tests the influence of various IT infrastructure roles on IS effectiveness. The study shows how different roles contribute to IS effectiveness in different ways. For example, the Common IS core and Strategy Enabler roles are positively related to almost all effectiveness items. The Flexible Platform role has a significant correlation with only one effectiveness item. IT infrastructure properties have different values in different IT infrastructure roles or views. For example, if IT infrastructure is used for strategic purposes, more flexibility and capability are needed than if IT infrastructure supports only basic transactions.

Every company must be aware of the role of IT infrastructure in the company and what possibilities IT infrastructure provides for leveraging. When discussing IT infrastructure, the question is not only about how much money to spend. That money must be tied to the company's business and IT strategies, which are interdependent with each other, and which define how IT infrastructure must be developed and maintained in order to support business. IT infrastructure should reflect the strategic context of the firm. According to Weill and Broadbent (1998), this strategic context, together with synergies attainable by the business units, and the long-term and current business strategies of the firm constitute the business requirements for IT infrastructure. These requirements are expressed in written sentences, called business maxims. Business and IT management derive IT maxims from business maxims. Firm-wide IT infrastructure is implemented according to IT maxims. This process is called 'management by maxim'. Xia and King (2002) emphasize business processes in their IT infrastructure definition: '*IT infrastructure* 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'.

2.3.3. Evaluating Dimensions of IT Infrastructure

IT infrastructure is a complex entity, as it contains both technological and human components, and combinations of both. Lewis and Byrd (2003) attempt to evaluate these elements with an instrument which measures the degree of implementation of activities within companies on a 1-6 scale. The dimensions describing the activities are Chief Information Officer, IT planning, IT security, Technology Integration, Advisory Committee, Enterprise Model, and Data Administration. All these dimensions are processes or functions necessary for the proper maintenance and development of IT infrastructure. For example, the Chief information Office dimension includes activities such as "CIO is responsible for corporate-wide information systems and technology policy" and "CIO is involved in the corporate business planning process". The instrument is one of the first endeavors to assess the readiness of IT infrastructure within firms, and it also guides practitioners in establishing necessary processes related to IT infrastructure.

2.3.4. Processes of IT Infrastructure in International Companies

When discussing international companies, we must remember that their firm-wide IT infrastructure usually extends across national borders. Evaristo and Munkvold (2002) call this a collaborative infrastructure, which comprises hardware, telecommunication networks, software (e.g. various forms of collaboration technology, such as conferencing tools, applications sharing, workflow etc.), organizational routines for using technology (including the allocation of roles and responsibilities), and finally some support apparatus offering both technical and procedural support in the application of the technology. Evaristo and Munkvold (2002) point out that IT infrastructure supports a variety of differing projects, where the scale of projects can vary from single location to multiple location, from single to multiple projects, from intra- to interorganizational locus, and from homogenous to heterogeneous culture. These dimensions raise further issues for consideration in connection with implementing and dealing with firm-wide IT infrastructure. There are challenges with people (eg. cultural differences, language barriers) and technology (eg. availability, reliability, compatibility and discrepancy of software).

Evaristo and Munkvold (2002) present a three-level model showing how collaborative IT infrastructure should be implemented. On the first level is technology IT infrastructure (eg. hardware and network, layer 1), which is implemented and tested before any other projects are started. Thus the technology component layer should be ready and working smoothly first. On the second level, software availability with support is secured and tested before giving it to users. This is how IT infrastructure services, including the necessary technology and software, are produced. These are services such as database management, printing services etc. The services are comparable with layer 3 of the layer model. On the third level, the instructions provided are meant not only to support current projects but also to facilitate upcoming ones. These are the instructions for IT infrastructure services. They encompass the building and maintenance of the IT infrastructure as an entity. Depending on the nature of the project, different emphases must be placed on the subjects within the model. For example, in a global project the emphasis is on the evaluation of technical readiness, of the availability of products, of cultural differences and of the quality of instructions. When IT infrastructure is in place, these more detailed instructions, the IT architecture and the IT strategy demand continual maintenance and updates.

3. Conclusion

The objective of the study was to assemble available, essential information on IT infrastructure from different studies into one model. The model was produced and further elaborated using the concepts of structure, properties and processes of IT infrastructure.

The **structure** of IT infrastructure is described in a number of ways, but the elements for describing it remain largely the same. The foundation is formed by the technology components, which human IT infrastructure uses to provide the required IT services for business needs. There are many kinds of standards with defined related processes, which channel the development and maintenance of IT infrastructure for business purposes. IT infrastructure must be built and maintained so that it is sufficient for the internal requirements of the firm, but also to fulfill the external requirements for connection to public or industry based infrastructure. Some studies emphasize certain elements more than others. However, it can be stated that current literature holds a common understanding of what IT infrastructure actually is, even though this understanding can be presented in a variety of ways. This study has tried to cover all these elements, as depicted in Figure 2.

The **properties** of IT infrastructure are described in an inconsistent way in current literature. The studies reviewed do not provide a clear distinction between when and how to use certain properties. On a general level, it can be said that more flexibility is needed when a company uses IT infrastructure to support new challenges. Thus, the required components for various layers of IT infrastructure must be easy to add and/or remove. Whereas flexibility focuses on modularity and the speed of IT infrastructure in supporting new challenges, capability focuses more on the amount and level of IT infrastructure services. Finally, effectiveness is used to evaluate IT infrastructure mostly from the user point-of-view.

There continues to be a need in the scientific community to show how these properties contribute to business objectives. This difficulty has already been discussed in several prior studies (e.g. Duncan, 1995a; Byrd and Turner, 2000). Even research has been conducted in this area (e.g. Byrd and Turner, 2001), more studies with empirical validations are needed to confirm and develop the properties of IT infrastructure. Thus the various properties can come to complement each other, and more valid and reliable results can be expected of IT infrastructure evaluations, in relation to the essential related qualities. Therefore, it is suggested that scholars conducting research on IT focus their attention either on IT infrastructure as an entity, or on the developed and presented elements, properties and processes of IT infrastructure, or a combination of these. This should lead to more reliable and valid research results and thus an increased understanding of issues involved.

Processes is the term used in this study to describe how IT infrastructure is valued. Indicators of IT infrastructure properties are only one way of evaluating IT infrastructure, but because IT infrastructure consists of so many elements (e.g. technical, human), it is difficult to define the value of the whole. In addition, different organizations even within the same industry value and require different things from their IT infrastructure. However, a low level of unity of IT infrastructure requirements can be seen at the industry level (Weill and Broadbent, 1998), and basically the same processes are needed for proper function in every organization (Lewis and Byrd, 2003). Even so,

exactly the same IT infrastructure can be very valuable to one company and almost worthless to another. The value requirement must be tied to the company strategic context, from which the requirements for building IT infrastructure are derived. The main problem of valuing IT infrastructure investments is that IT infrastructure creates the foundation for other IT investments, but its value is more difficult to measure. IT infrastructure requires a significant part of the IT budget, but its value appears in many different forms, such as decreased transaction costs or increased speed in implementing applications. However, at the same time, depending on the chosen role or view of the IT infrastructure, it can provide a variety of possibilities for implement fulfilling a wide range of business requirements.

IT infrastructure is a discrete part of IT which should be treated separately in different contexts such as management and outsourcing. This is because the features of IT infrastructure, such as stability, differ from those of rapidly changing business applications. IT infrastructure stands for a huge part of IT, and in order to receive even more attention, it should show up as an element separate from other IT issues in future studies. Further research is needed on IT infrastructure, also with a focus on developing and presenting reliable, valid measures of IT infrastructure processes. This, in turn, can and will help to facilitate the understanding and evaluation of IT infrastructure in its changing and evolving contexts and environments.

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