19 APPROACHING INFORMATION INFRASTRUCTURE AS AN ECOLOGY OF UBIQUITOUS SOCIOTECHNICAL RELATIONS

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Abstract *In this paper, we seek to understand the ecology of ubiquitous sociotechnical relations involved in the development and use of information and communication technologies. We draw on some examples from an empirical case study on the development and use of a regional healthcare information technology network to illustrate our conceptualization of this information infrastructure as an ecology. We conclude with some implications for theory and practice.*

Keywords Information infrastructure, ecology, sociotechnical analysis, interpretive case studies

1 INTRODUCTION

The development and use of information and communication technologies (ICTs) takes place in an organizational context and is usually affected by the existing human and technological base or infrastructure. ICT projects may also be affected by surrounding environmental factors such as local political reforms or global changes that are beyond the control of project managers. More recently, researchers from diverse fields have coined the term information infrastructure to explain the complexity of factors and multiplicity of outcomes involved in large-scale ICT projects (e.g., Bowker and Star 1999; Ciborra et al. 2001; Hanseth and Monteiro 1997; Star and Ruhleder 1996). The

underlying argument of this literature is that new technology is never developed from scratch but rather "wrestles with the 'inertia of the installed base' and inherits strengths and limitations from that base" (Star and Ruhleder 1996, p. 113). In other words, new technologies emerge on an already existing ecology of ubiquitous sociotechnical relations.

In this paper, we seek to go beyond existing knowledge by un-blurring the different layers of this ecology and contributing to a richer understanding of information infrastructure. To this effort, we draw on some of the theoretical developments of Latour (1999) and Peirce (1931-1958). Peirce's work will help inform our understanding of the process by which meanings are developed and transformed by an individual or between members of a community, as well as the ways in which knowledge becomes grounded in practice. Latour's ideas will help inform our understanding of the relationship between the social world and the world of technological artifacts. This theoretical mix of ideas will help us to distinguish between seven unique but interdependent layers of information infrastructure and the negotiations that take place between them. We illustrate these theoretical developments by drawing on a longitudinal, interpretive case study on the development and use of a regional healthcare IT network in Crete.

2 UNDERSTANDING INFORMATION INFRASTRUCTURE

We start the discussion by representing and organizing existing knowledge on information infrastructure according to the two most frequently referenced bodies of research. The first body of research gravitates toward the tendency of business schools to employ a positivistic epistemological stance, combined with the functionalist influence of computer engineers, while seeking to develop management agendas for the maximization of strategic business–IT alignment (Henderson and Venkatraman 1993; Weill and Broadbent 1998). The second body of research is "less immediately concerned with modeling and prescriptions" (Ciborra et al. 2001, p. 21) and more interested in an interpretive understanding of information infrastructure, while immersing itself in the multilevel context of sociotechnical processes (Bowker and Star 1999; Ciborra et al. 2001). We next discuss these diverse bodies of research in more detail while seeking to uncover some key themes to understanding the concept of information infrastructure.

2.1 Management Agendas Toward Strategic Business–IT Alignment

The first body of research views information infrastructure as the fundamental component of a firm's IT investment portfolio, which aims at maximizing business value by implementing "a number of as-yet-unspecified business strategies…more rapidly" (Weill and Broadbent 1998, p. 101). Based on this general view, the proponents of this body of research seek to define the *reach* and *range* of information infrastructure

(Duncan 1995), its *reusability* or *modularity* (Chung et al. 2003; Duncan 1995), and the *intangible resources* that it requires, such as human knowledge and skills, commitment, and competencies (Chung et al. 2003; Henderson and Venkatraman 1993; Weill and Broadbent 1998).

Based on these concepts, the key proponents of this body of research propose two approaches to managing a firm's information infrastructure, namely, management-by-maxim and management-by-deals (Weill and Broadbent 1998). On the one hand, the maxims approach refers to the development of firm-wide enforceable initiatives such as constructs for measuring the flexibility of information infrastructures (Byrd and Turner 2000; Duncan 1995), as well as a series of leadership principles for managing the emergence of new technologies (Weill and Broadbent 1998). On the other hand, the deal-making approach refers to political power issues and an uneven establishment of information infrastructure. Although the deal-making approach is present in approximately 40 out of the 80 cases examined by Weill and Broadbent (1998), the authors seem to lean in favor of the maxims approach. However, extensive review of top managers' opinions related to the actual management of information infrastructures points out that new technologies evolve in the interplay between multiple and contradictory forces, including unplanned systems requirements emerging from the lack of IT knowledge and the skills of the users (Chung et al. 2003; Duncan 1995). Thus, even though this first body of research has offered some valuable insights for our understanding of information infrastructure, we suggest that this conceptualization does not go far enough in accounting for the ongoing negotiations and interplay between sociotechnical relationships associated with the development and use of new technologies in organizations.

2.2 Interpretive Explanations of the Multilevel Context of Information Infrastructure

In their criticism of functionalist accounts of information infrastructure, some researchers argue that alignment is "heterogeneous, meaning that there is an open-ended array of 'things' that need to be aligned, including work routines, incentive structures, training, information-systems modules, and organizational roles" (Monteiro 2001, p. 72). Thus, alignment is an ongoing sociotechnical process and information infrastructure is a *heterogeneous* collage of different layers of technological components, people, institutions, and so on (Hanseth 2001; Hanseth and Monteiro 1997). In this view, technological artifacts have an equal role to play in the process of change (alignment to new goals). Specifically, by employing the theoretical lens of actor-network theory (ANT), researchers in the interpretive tradition are found to pay particular attention to the inscriptions carried in the features and functions of technological artifacts, which correspond to the efforts of the more dominant groups to implement specific programs of action. Based on this view, an information infrastructure becomes an actor by enforcing programs of action on its users, i.e., the roles to be played by each participant in the overall network (Monteiro 2001). For example, in an interpretive case study on the development of a customer relationship management (CRM) infrastructure at IBM, Ciborra and Failla (2001) argue how, by building the main steps of CRM on Lotus

Notes, IBM was able to "freeze the CRM discipline in silicon" (p. 117). The growing use of Lotus Notes by IBM employees increased the scope and depth of control of CRM processes by "'enforcing' globally behaviors on how to run the business" (Ciborra and Failla 2001, p. 118). Of course, the inscribed programs of action may not succeed because the actual use of IT may deviate from those; users may use the system in ways unanticipated by designers; they may follow an anti-program of action (Latour 1991). To this realization, more recent research employing the ANT terminology has been more careful in accounting for multiple views and multiple aspects of actor-network formation (Ellingsen and Monteiro 2003; Rolland and Monteiro 2002). However, ANT studies have been criticized for privileging the viewpoint of the designer or the manager, whose ability to inscribe certain behaviors on technological artifacts is deemed critical for the expansion and sustainability of a given actor-network (Bowker and Star 1999; Haraway 1988; Star and Griesemer 1989).

In an attempt to address these limitations, some researchers in the interpretive tradition have instead immersed themselves in an exploration of multiple viewpoints while acknowledging that several outcomes are simultaneously being negotiated by different groups and individuals (Bowker and Star 1999; Star and Griesemer 1989; Star and Ruhleder 1996). This group of researchers argue that first, an information infrastructure, just like any other technological artifact, is *learned as part of membership* in a community, and second, that an information infrastructure both *shapes and is shaped by the conventions of a given community*. In this respect and in contrast to ANT's focus on inscriptions of programs of action in artifacts aspiring to favored obligatory passage points (Latour 1991), this group of researchers argue that there is an indefinite number of ways in which entrepreneurs from different participating communities may create alternative passage points or outcomes in their own world (Star and Griesemer 1989). For example, after studying the development of a large collaborative system codesigned with a scientific community, Star and Ruhleder (1996) found that, despite good user prototype feedback and participation in the system development, there were unforeseen, complex challenges to usage involving infrastructural and organizational relationships. These challenges were born from such silent elements as feeling shame, fear, and rage, or from lying (to the point of claiming to use the system and not using it, or using one system to show the evaluators and then switching back to familiar technology in their routine work) (Star and Ruhleder 1996). These are the kinds of politics in action to which we should be paying attention (Bowker and Star 1999). The study of politics in action entails an understanding of the relationship of people with participant communities of practices, as well as an understanding of the ways in which artifacts and material arrangements become taken for granted in those communities (Bowker and Star 1999). Such an understanding aims at allowing for multiple voices to be heard, while also opening up possibilities to "disembed the narratives" contained in new technology development and use, and unearth the deeper social structures embedded in the broader organizational context (Star 2002, p. 110).

2.3 Summary of Key Themes

A first theme emerging from this brief review of the literature refers to the importance of moving away from functionalist, managerial views, which tend to treat

information infrastructure as just another resource to be steered by upper management so as to achieve a maximum alignment to the business objectives of the given organization. We need to approach information infrastructure as an ever-evolving sociotechnical ecology of people, institutions, artifacts, and practices. To understand the different layers of the information infrastructure ecology, we need to acknowledge both the intentions and meanings of different groups and individuals, but also the dynamic role of technological artifacts in mediating those meanings and intentions.

A second theme refers to the importance of paying attention to the multiplicity of outcomes being negotiated by diverse groups and individuals in their work and social contexts at different points in time and space. While examining the intentions and meanings of the more dominant groups (e.g., senior managers) may help us understand how new technologies are conceptualized and developed, we will only be able to understand their implementation, use and scale-up or collapse if we disembed the underlying sociotechnical relations involved in the broader ecology.

The next section will attempt to go beyond these themes and contribute to a richer understanding of information infrastructure.

3 APPROACHING INFORMATION INFRASTRUCTURE AS AN ECOLOGY OF UBIQUITOUS SOCIOTECHNICAL RELATIONS

In this section, we draw on some of the theoretical developments of Latour (1999) and Peirce (1931-1958) to understand information infrastructure as an already existing ecology of ubiquitous sociotechnical relations and their respective crossovers. The term *crossover* is borrowed from Latour (1999, p. 194) to refer to the "exchange of properties among humans and nonhumans" in the process of their interaction to achieve different goals. Figure 1 outlines the discussion that will follow.

3.1 Individuals

We start our discussion with the abstract relations of individuals with their surroundings and the way in which ideas become conceptualized before being materialized and grounded in practice. This is linked to Peirce's (Vol. 2, § 300) ideas of a semiotically constituted world, whereby individuals experience their surroundings as *signs* standing for specific *meanings* to refer to specific *objects* (e.g., actions, events, artifacts). This interpretive process between signs–meanings–objects continues until a *habit* is created or transformed in the mind of interpreting individuals (Peirce 1931-58, Vol. 5, § 476). For Peirce, *habit* refers to a kind of disposition or rule of conduct, guiding our thoughts and actions about a given object, event, and so on (Vol. 7, § 468-523). Thus, what Peirce is suggesting here is that all knowing is a process and habits are created or transformed through inferences of past experiences.

To better illustrate this interpretive process consider the following example. In an empirical case study on the development and use of a regional healthcare IT network in

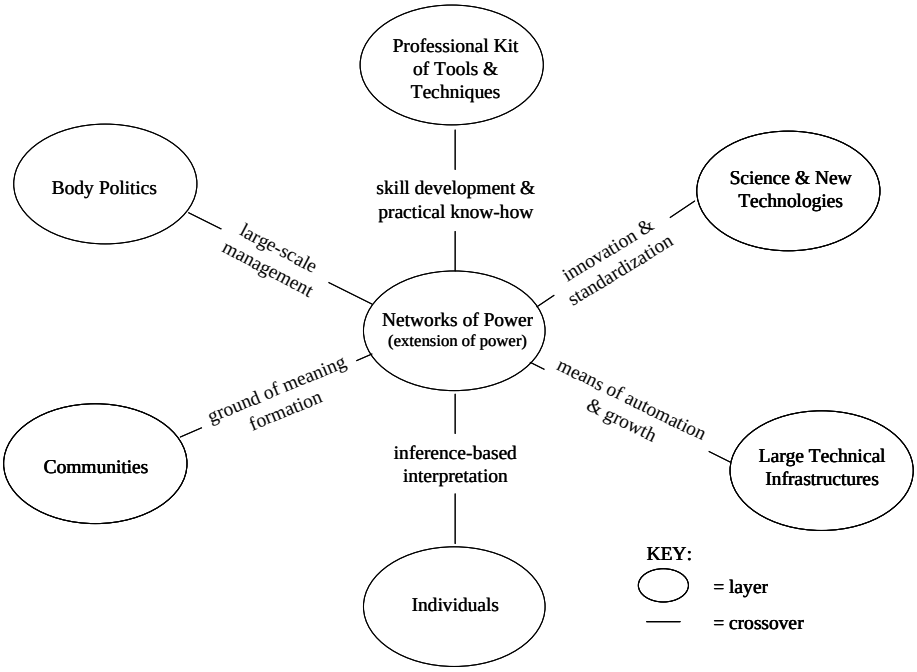

Figure 1. Information Infrastructure as an Ecology of Ubiquitous Sociotechnical Relations

Crete, we had the chance to observe a group of cardiologists using a telemedicine system to provide consultation to general practitioners (GPs) for patients with cardiac problems. The system offered an alternative to the practice of calling cardiologists on the phone and/or transferring patients with possible cardiac problems from primary healthcare centers to the hospital where the cardiologists work. The system added on the capabilities of simple phone calls by enabling the exchange of patient data such as electrocardiographs between GPs and cardiologists and minimized unnecessary patient transfers to the hospital. Even though the system offered these benefits, the actual practice of consultation rested on the cardiologists' inferences of past experience and knowledge and the information provided by the GPs. Furthermore, the practice of providing a final diagnosis rested on the physical examination of the patient by the cardiologist. As a cardiologist explained,

> *For me to give a diagnosis I have to see the patient's X-ray, also have a look at his ECG [electrocardiograph] and compare them, perform an ultra sound examination on him, etc., and then decide what is wrong with him.…You start with the initial suspicion and you eliminate possibilities as you go along, by doing more tests and examining more things.*

Thus, linkages between existing meanings (e.g., meanings about cardiac conditions), new information (e.g., medical signs about the patient), and new actions (e.g., the

physical examination of the patient), are established only through a process of inference-based interpretation.

3.2 Professional Kit of Tools and Techniques

This interpretive process is mediated by a series of tools and techniques, which individuals use to achieve certain objectives (Latour 1999). In the above example, the GPs employed an ECG device to generate an ECG of the patient, the telemedicine system to send the ECG to the cardiologist, and so on. This professional kit of tools and techniques is filtered until it becomes part of the individual's habits. Certainly, although some tools and techniques will survive the filtering, others will be discarded for not being able to fulfill the purpose of the individual's existing habits. Still others may be kept for other purposes based on other habits. In this respect, although tools and techniques may be devised and shifted (accommodated to fit certain objectives) by different individuals, their meaning will be completely independent of their use. For example, in the Crete case study, the telemedicine system, by itself, represented no action and consequently no meaning; in the hands of an initial group of self-motivated cardiologists and GPs, the telemedicine system provided a means with which to make sense of and produce diagnoses for patients with cardiac problems; in the hands of a group of GPs, who were later integrated to the network of participating physicians, the telemedicine system represented a poor alternative to existing practices because in the case of an emergency "it will be too slow of a response… so, the use of the system is not very practical," as one GP noted. Thus, different individuals will choose to interpret the same set of tools and techniques differently at different times; some will focus on the advantages and others will focus on the disadvantages, others still will completely ignore newly introduced tools and techniques and refuse to let go of their existing, more familiar kit and know-how. This refers to the pliability of tools. Tools only gain some durability within a given context under the agreement of a community. As Latour (1999) notes, tools and techniques represent the extension of skills rehearsed in the realm of social interaction.

3.3 Communities

A community is formed at the point when a shared inquiry eventually points toward a common set of meanings, agreed upon by all participants in the inquiry (Peirce 1931-1958, Vol. 5, § 407). Once formed, a community represents the realm of social interaction whereby community members ground their interpretations of their surroundings into common habits. A community, thus, establishes an association between the process of knowing in an individual's mind and the agreed-upon practices of a collective whole. Still, a community will not always consist of the same individuals and, thus, even though some members may remain, the community's common habits are bound to change and with it will change the kit of existing tools and techniques. For example, in the Crete case study, the telemedicine system was initially embraced by one GP at a rural primary healthcare center and three cardiologists at a district hospital,

forming an initial community of collaborators. However, when six more primary healthcare centers were integrated into the network, the community's common habits were seriously challenged by new interpretations and new members. The new members not only challenged existing meanings about the technology, but also challenged the practicality of its use. These ideas point to Peirce's notion of a "true continuum…whose possibilities of determination no multitude of individuals can exhaust" (Vol. 6, § 170). In a true continuum the possibility of reaching new meanings about a given reality is potentially unlimited. Thus, as interpretations drift, communities also continuously drift.

3.4 Large Technical Infrastructures

The conservation and growth of community ties depends on the ability of the community to "naturalize" (Bowker and Star 1999) its professional kits into large technological infrastructures. These infrastructures accumulate the professional kits of different communities with the goal to automate activities, ensure the distribution of resources, and provide a common substructure upon which more tools and techniques can grow. Like professional kits, these infrastructures become transparent in practice, taken for granted; they sink into the background only to become visible again when they break down or when they become used in a completely different way from the originally intended use (Star and Ruhleder 1996). For example, in the Crete case study, CreteTech, the private institute behind the efforts to create a regional healthcare IT network in Crete, not only developed and implemented the aforementioned telemedicine system, but also a series of other tools such as an electronic patient record system and a primary healthcare center information system. These tools were initially implemented selectively at three primary healthcare centers and a district hospital, which were thought to be more technology receptive. After some initial success, CreteTech, with the agreement of the initial group of participating physicians, proceeded with the implementation of the aforementioned systems to the rest of the regional healthcare centers in Crete in an effort to scale up the pilot. For some time, the regional healthcare IT network became transparent in use, until it started to break down, unused even by the initial group of users. The reasons behind this breakdown are not only connected to the capabilities and functions of the introduced technologies, but also intimately dependent on the presence or lack of a body politic.

3.5 Body Politic

A body politic refers to a *body*, the ecology of individuals, professional kits, communities, and infrastructures, and a *politic*, the framework of formal and informal rules and resources needed for managing the body. Thus, the politic represents the body's ground of meaning formation, which is less easy to mold than the ground of a given community, but which provides a common means for sense making among diverse communities. For example, in our empirical case study, the development and implementation of the regional healthcare IT network was a project initiated by

CreteTech with the support of some key stakeholders in the region of Crete. The success of this pilot project was recognized at the 2003 European eHealth awards when it received an honorable mention for its technologically advanced design. Despite this, however, neither the government nor any other agency supported the project. As an engineer at CreteTech explained,

> *The overall effort was a pilot project, but unlike other government and private projects it wasn't expected to be used on a routine basis. Doctors or other users weren't obliged to use it; they could either use it or not. Since we are not part of the Ministry of Health we don't have the authority to demand the use of the system and there wasn't such an issue anyway since this was an R&D project.*

In other words, the pilot project never received the formal support of the national and regional body politics. In consequence, CreteTech lacked the necessary authority to effectively manage and scale up the project throughout the region of Crete, something that ultimately led to the breakdown of the healthcare IT network.

3.6 Science and New Technology

Apart from professional kits and large technical infrastructures that provide a means for automation and growth for a given community or body politic, there is also science and the emergence of new technologies including such specialized equipment as medical imaging scanners. Such scientific objects may bring about dramatic transformation to the other layers of the information infrastructure ecology, often without the intention of a particular body politic or community. However, there is another important function attributable to this layer: standardization. Standardization is often not only a response to the need of making things commonly accessible, but more usually a response to new inventions and ways of integrating those to an existing infrastructure. This can be observed in the efforts to introduce a series of technological standards to respond to the emerging need of developing healthcare information infrastructures (Hanseth and Monteiro 1997).

In the Crete case study, although the healthcare IT network has collapsed, CreteTech's efforts to introduce such international standards as the Health Level 7 in the work practices of physicians in the region have continued apace. The regional health authorities of Crete have recently announced an open competition for the development of a regional healthcare IT network that incorporates many of the standards introduced by CreteTech during the pilot project. In this sense, the dynamic crossovers between the different sociotechnical layers, including CreteTech's commitment to state-of-the-art research and development projects, as well as the strong interest of a number of key healthcare professionals in the region to use new ICTs in their work practices, have brought about unexpected transformation in the existing ecology. After a long process of dynamic sociotechnical crossovers, the regional ecology of Crete is now more receptive to technological developments. However, this dynamic transformation will be negotiated in networks of power.

3.7 Networks of Power

The term *networks of power* is borrowed from Latour (1999) and refers to hybrids of humans and nonhumans and how both can equally mobilize (spread and extend) each other's strength and durability (i.e., how nonhumans can become standards and how humans can build enduring power relationships). In this sense, in the information infrastructure ecology, networks of power are ubiquitous (i.e., existing in all layers between key individuals and bodies politic, as well as their professional kits and infrastructures).

In the Crete case study, the CreteTech team initially managed to mobilize their efforts from the bottom up by gaining the support of a group of physicians. However, this network of power was later mediated by an intellectual property rights dispute between the director of CreteTech and a key official at the regional health authority over the development of electronic patient records in the region. As this example illustrates, the struggle for power is equally mediated from the bottom up as it is from the top down. Thus, networks of power sit in the center of the information infrastructure ecology, accumulating strength or succumbing to the weaknesses of the other layers.

4 IMPLICATIONS FOR THEORY AND PRACTICE

In this paper, we sought to go beyond existing knowledge and further our conceptual understanding of information infrastructure by unearthing its heterogeneous character. In so doing, we have realized information infrastructure as an already existing ecology of ubiquitous sociotechnical relations and their respective crossovers.

A key implication for theory refers to the need to take into account both the intentions and meanings of different groups and individuals, but also the role of technological artifacts in mediating those meanings and intentions. By drawing on Latour's (1999) collective of humans and nonhumans, as well as on some of Peirce's (1931-58) key theoretical developments, we have provided some useful analytical tools for theorizing change and development in the different layers of the information infrastructure ecology as wrought by the introduction of new ICTs. These conceptual developments have not only created possibilities for explicitly theorizing each of the layers of the information infrastructure ecology, but also understanding the multiplicity of outcomes being negotiated between human agents and their choice of artifacts at different points in time and space.

The importance of these conceptual developments is highly relevant for researchers and practitioners alike. In fact, a key implication for practice is the need to approach the development and use of new ICTs as an ongoing process of negotiation between human agents and their choice of artifacts. This process can only be understood through a clear description of the existing ecology of ubiquitous sociotechnical relations in which new technological artifacts are developed and used, including existing power relationships, relevant standards and their implications, participant bodies politic and their structural arrangements, existing infrastructures and artifacts and their mediating role, participant communities and their grounds of meaning formation, and key individuals and their

interpretations. Only after analyzing the subtle mechanism of the dynamic crossovers between the different layers in the information infrastructure ecology can we begin to inform our management practices. In this sense and by accepting Latour's (1999, p. 214) suggestion that "humanity rests in the crossover," Figure 1 extends the theoretical contribution to issues of management and practice. Employing this figure as an epistemological starting point, we may not only inform the ways of theorizing information infrastructure, but also the ways of managing the crossovers between its different layers.

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