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Claudio Ciborra
Università di Bologna

Ole Hanseth
Universitetet i Oslo

TOWARD A CONTINGENCY VIEW OF INFRASTRUCTURE AND KNOWLEDGE: AN EXPLORATORY STUDY

Claudio U. Ciborra
Università di Bologna, Italy
Universitetet i Oslo, Norway
Gøteborgs Universitet, Sweden

Ole Hanseth
Universitetet i Oslo, Norway
Gøteborgs Universitet, Sweden

Abstract

IT infrastructures coupled with BPR initiatives have the potential of supporting and enabling new organizational forms and helping firms face the challenges of globalization. The management literature gives prescriptions of how to set up, implement, and use infrastructures to reach a new IT capability; diminish transaction costs; and obtain competitive advantage. However, the scant empirical basis of such literature goes hand in hand with the lack of a theory linking the deployment of infrastructure to the nature of the business and the industry. This study of the deployment and use of infrastructures in six large multinationals sets the ground for a contingency approach to the whole issue. The different implementation processes and applications reported by the case studies suggest that there is much more variety than the "one best way" recommended by the literature. The economic theories of standards and of the firm as a repository of knowledge are good candidates to explain qualitatively the empirical evidence.

Keywords: Information infrastructures, IS use, globalization of IS, economic theory, implementation approaches.

1. INTRODUCTION

Managing an infrastructure to deliver effective information technology (IT) capability today means dealing with problems such as aligning strategy with IT architecture and key business processes (Henderson, Venkatraman and Oldach 1996); universal use and access to IT resources; standardization; interoperability of systems and applications through protocols and gateways; flexibility, resilience, and security. Ideally, infrastructure reconciles local variety and proliferation of applications and usages with centralized planning and control over IT resources and business processes (Hanseth 1996; Weill and Broadbent1997).

However, the more one looks at how large corporations are setting up and deploying IT infrastructures, often in connection with BPR projects (Broadbent, Weill and St. Clair 1995), the more the picture emerging is fuzzy: strategic alignment does not fully explain the dynamics of implementation (Ciborra 1997; Sauer and Burn 1997), and power games prevail over efficiency considerations (Knights, Noble and Willmott 1997). At the limit, infrastructures seem to "drift" (Ciborra 1996), or be created by planning as well as by improvisation (Orlikowski 1996).

To appreciate the dynamics of corporate infrastructures, an exploratory study has been carried out in six multinationals: IBM, Hoffmann-La Roche (Roche), Astra, SKF, Statoil, and Norsk Hydro (see also Hanseth and Braa 1998). The deployment and use of infrastructure have been followed up in a variety of corporate functions: marketing; production; R&D, etc., focusing on the relationships between headquarters and affiliates. A number of technologies and relevant business processes have been analyzed, ranging from Lotus Notes platforms to office automation suites, SAP, Internet and Intranet, to dedicated systems, standards and protocols.[1]

The data collected seems to confirm the initial awareness: infrastructures "in action" differ from the neat icons provided by the management literature. For example, they cannot be classified in just three types (utility, dependence, enabling), (Weill, Broadbent and St. Clair 1996), since they drift from one use mode to another with no apparent logic. The implementation process is far from being straightforward, but is punctuated by opportunistic moves and power games (Murray and Willmott 1997). A theory able to predict success or failure of an infrastructure project is still missing. While IT infrastructure capabilities do vary according to industry (Broadbent et al. 1996) emerging applications such as Lotus Notes or SAP are being adopted across all industries. This tends to confound the evidence of a difference. If infrastructure varies with the intensity of "business unit synergy," there still can be radically different ways of achieving such a synergy (e.g., by interlocking processes through BPR, or providing a common business template through Web sites). Since the planning process is so punctuated by surprises, chance, and opportunistic adjustments, in none of the cases could a correlation be established between emphasis on strategic intent, management backing, and infrastructure deployment. In one case, Roche, just the opposite has occurred: only by "releasing" management control could a new infrastructure emerge.

This paper attempts to link the empirical study of infrastructure *in situ* with economic theory. Two streams of economic thinking are utilized: the economics of infrastructures, in particular standards (Grindley 1995), and the theory of the firm emphasizing its knowledge processing properties (Nelson and Winter 1982). These theories are harnessed to understand what happens to corporate infrastructures in practice: their development, use, impacts, and success (i.e., widespread and self-sustaining use). The nature of the knowledge processes during implementation and in the business appears to be an important factor for explaining the variety of outcomes in the cases.

2. ECONOMIC PERSPECTIVES

Two relevant aspects of the life of an infrastructure, i.e., its deployment and the tasks to which it is applied, can be analyzed by tapping into the economic theories of standards, firms, and industry infrastructures.

2.1 The Implementation Process

Schematically, a typical management agenda concerning corporate infrastructure entails the following:

- Analysis of the firm's strategic context to elicit the key business drivers;
- A joint consideration of the need to improve or transform existing business processes and infrastructures;
- Formulation and implementation of BPR and technical change plans;
- Envisioning changes in roles, responsibilities, incentives, skills, and organizational structures required by BPR and infrastructure reforms (Broadbent and Weill 1997).

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[1]The research project on "The Dynamics of Global Infrastructures" was started in the autumn of 1997. The field work has been completed at the time of writing. The research team comes from three European universities and is composed of 10 academics. An average of 20 people have been interviewed, each for more than two hours, in seven different countries, including the U.S. The methodology of multiple case design was followed (Yin 1993).

One should be wary of this "one best way" kind of agenda, since it hides a number of dilemmas, such as: Is it better to build a flexible infrastructure that enables a wide range of unplanned business redesign options, or a highly consistent (i.e. aligned) infrastructure with the current strategic intent? Is there a trade-off between alignment and flexibility? Extensive studies of top managers' opinions do not lead to any clear-cut conclusion (Duncan 1995).

While management agendas tend to be precise in guiding the *formulation* of an infrastructure plan, they do not give any special advice on *implementation* and adaptation. They only provide words of caution (Broadbent and Weill 1997; Luftman 1996), but these do not suffice to translate a sound plan into its production (Argyris and Schoen 1996).

Economics of standards and network infrastructures (Hanseth 1996; Hanseth, Monteiro and Hatling 1996) can overcome the sometimes narrow "information engineering mindset" that lures in the managerial discourses about infrastructure. Consider issues such as the trade-off between universal service type of delivery vs. a customized service; how to reach a *critical mass* of infrastructure users? Who should benefit or pay for the positive and/or negative *externalities* generated by infrastructure use?

A balanced answer to such questions is a key factor for the take off and long term development of any infrastructure. In particular, the issues of public goods and externalities point to an important topic: the scope for control over an infrastructure is limited, and management has to live with a resource that they can govern only in part (pending the issue of transaction costs [Coase 1960]). Hence, the governance of infrastructure is a problem, not a given, since there can be multiple stakeholders with conflicting interests. The net result can be an infrastructure that expands and grows in directions and to an extent largely outside the control of any individual stakeholder.

Building large infrastructures takes time. All elements are connected. New requirements appear to which the infrastructure must adapt. A whole infrastructure cannot be changed instantly: the new has to be connected to the old. Hence, the old—the installed base—influences how the new is designed. Infrastructures develop through extending and improving the *installed base* (Hanseth 1996).

A large information infrastructure is not just hard to change. It might also be a powerful actor influencing its own future life because of its extension and size as well as its form. Consider the issue of "standards" as a part of a more general phenomenon labeled "self-reinforcing mechanisms" (Arthur 1996) and "network externalities" (Katz and Shapiro 1986). A standard that builds up an installed base ahead of its competitors becomes cumulatively more attractive, making the choice of standards "path dependent" and highly influenced by a small advantage gained in the early stages (Grindley 1995).

Other key effects of self-reinforcing mechanisms are:

- *Lock-in*, i.e., when a technology has been adopted it will be impossible to develop competing technologies;
- *Possible inefficiency*, i.e., the best solution may not necessarily win (David 1987).

Information infrastructures are paradigmatic examples of phenomena where "network externalities" and positive feedback (increasing return on adoption) are crucial and, accordingly, technologies that are easily locked-in and turn irreversible.

Designing and governing an infrastructure differ from designing an MIS, due to the far reaching influence of the installed base and the self-reinforcing mechanisms. The very scope of the management agenda changes. Infrastructure is not just a complex, shared tool that management is free to align according to their strategy. The economic perspective highlights a more limited and opportunistic agenda involving trade-offs and dilemmas, and a number of tactics. David (1987) points out two dilemmas in developing networking technologies:

- *Narrow policy windows.* There may be only brief and uncertain "windows in time," during which effective interventions can be made at moderate costs;

- *Blind giants.* Decision makers are likely to have greatest power to influence the future trajectories of network technologies just when suitable knowledge on which to make system-wide choices is most lacking.

In sum, while from an engineering and managerial perspective the task is to design, build, align, and control an infrastructure, the thrust of the economic understanding of the dynamics of infrastructures points out that "cultivating" (Dahlbom and Janlert 1996) an installed base is a more realistic option. The concept of cultivation focuses on the limits of rational, human control (Simon 1976). Also, one should expect to find a variety of implementation processes when dealing with infrastructures: the actions of multiple stakeholders and their limited scope, externalities and transaction costs, combined with the influence of non-linear development processes make the outcome of any implementation less predictable than the management and engineering literature would like us to believe.

2.2 The Theory of the Firm

Why is an infrastructure useful? The management literature indicates that it allows the firm to run interlinked applications to process and communicate information seamlessly; it supports streamlined processes and enhances coordination. Unfortunately, theoretical developments about the role of core capabilities (Prahalad and Hamel 1990), the resource-based view of strategy (Barney 1991), and the model of the knowledge creating company (Nonaka and Takeuchi 1996) tend to be largely ignored by the management literature. This is a pity, since the common denominator of these theories is the study of the firm as a collection of skilled people "who know what to do" (Nelson and Winter 1982), where their "Productivity...depends on ... the conditions that underlie the acquisition and use of knowledge"(Demsetz 1993). Furthermore, knowledge, both tacit and articulated, represents the key asset to obtain a sustainable competitive advantage. If firms are "treasuries of process knowledge" (Boynton and Victor 1991), infrastructure is one of the key resources needed to put knowledge to work, since the very business processes it supports are the embodiment of the know-how of the firm. Specifically, since "economic organization, including the firm, must reflect the fact that knowledge is costly to produce, maintain and use" (Demsetz 1993), infrastructure is a means to lower such costs by allowing its efficient processing, transfer and accumulation.

The knowledge embedded in products, services, and processes varies across firms and industries. In high-tech firms, workers are highly skilled, production processes are complex, and products knowledge-rich. Other industries, for example, the production of metal, may rely on processes that are stable, based on routine knowledge. A firm, or an industry, can migrate from a knowledge-poor to a knowledge-rich business. In general, the type of infrastructure does not vary arbitrarily; rather, it adapts in range and scope to the type of knowledge "embedded" in the firm and the industry.

The deployment of an infrastructure that affects the knowledge processing costs can impact the very nature of the firm. Namely, the infrastructure may alter the trade-offs between the different ways to economize on knowledge processing costs: direction(*hierarchy*), training/sharing (*teams*), and embedding knowledge into products to be exchanged across *markets* (Demsetz 1993). Direction aims at controlling through formalization and procedures of "continuous improvement" the way (especially explicit) knowledge is divided, accumulated and transferred. On the other hand, the other mechanisms coupled with the very characteristics of IT as a dynamic, open technology favor regimens of (tacit) knowledge leaking and spillovers within and across the boundaries of the firm, by which knowledge itself becomes an "infrastructure," and input to further processes of creation, innovation and recombination that can be widely decentralized and dispersed.

2.3 Knowledge, Infrastructure, and Control

So, what is the relationship between knowledge creation and use, information infrastructures and control? First, of course, we might have infrastructures, like groupware and Internet, supporting the knowledge creation, diffusion, and use processes. In such a perspective, we might consider the infrastructure and the knowledge processes it supports as independent.

Another perspective is to regard knowledge in itself as an infrastructure, a view that is gaining momentum in economics (Steinmueller 1995), specifically from studies of industrial districts as well as industries such as IT. These studies have found knowledge to be a "public good" that cannot be created or managed from the point of view of specific projects or products. It is a resource that has its highest value when it is shared by a large community and it is primarily created and used through "spillover" effects, where knowledge generated for one specific purpose is discovered to be useful, possibly in a generalized form, in a wide range of other areas.

Seeing knowledge as an infrastructure implies that the economic concepts presented above, like lock-ins, should apply even to knowledge in its "softest" sense, i.e., as something we have in our minds. And they do. As we are developing more complex and systemic technologies, our knowledge about the different parts of such systems gets more interdependent—just as the components themselves. The lock-in problem is illustrated by the difficulties in changing from one techno-scientific paradigm to another (Kuhn 1970).

Also, at the corporate level, we should not look at knowledge and technological infrastructure as something completely independent. IT infrastructure supporting knowledge creation and use embeds knowledge in various forms. In the weakest form, knowledge consists of documents in one format or another (Word, HTML, etc.). In the strongest form, it will be encoded in the formal language of an expert system. In between, we might have Lotus Notes databases and other groupware tools containing knowledge represented in multiple ways.

Seeing the firm as a "knowledge processing" entity raises the question about managing knowledge processes. Surrounding a ramified global infrastructure, spontaneous processes of knowledge use and creation obtain in ways that are not fully predictable. Since we cannot know what kind of knowledge will be created and, accordingly, we cannot plan in advance how to make use of it. This unpredictable character of learning processes makes them "inaccessible" for centralized management. However, as the knowledge obtained up to one point in time influences the next steps in the learning process, learning processes become path-dependent—just like for any heavy infrastructure. This path dependency also implies that centralized control will be limited due to the infrastructural nature of knowledge. On the other hand, a bottom-up organized process might lead to lock-ins, which impede learning as well. When learning is the crucial issue, counter-actions, as David proposes, will be a possibly important strategy.

The broader the knowledge stock being applied, the more standardized it needs to be. On the other hand, continuous learning means continuous change. This makes both standardization and flexibility crucial issues. Managing the tension between them lies at the core of all infrastructure development (Hanseth 1996), including "knowledge infrastructures."

3. TWO SELECTED COMPANY CASES

3.1 SKF

SKF is a Swedish multinational that produces bearings, operating in more than 130 countries, with production at more than 80 different sites and 43,000 employees. SKF has grown slowly, by successfully developing its organization and information technology in a gradual way. In the 1970s, it changed its strategy, shifting from independent and self-contained national companies into one global organization. Correspondingly, SKF decided to replace the existing collections of locally developed information systems with a collection of "common systems" and a global communications infrastructure (based on the SNA protocol). The implementation of this strategy has been going on ever since—and still is—by continuously integrating the functions within larger and larger areas. The infrastructure built over the last decades allows SKF to run global forecasting and supply systems through a variety of corporate applications, message transfer systems, and satellite links (Hagstroem 1991). For example, the International Customer Service System, installed in 1981, provides a key global interface between the sales and manufacturing units. Other systems are dedicated to master production scheduling, manufacturing, and finance. What is striking is that SKF seems to have always focused on production and has developed its infrastructure as a management information system for global production control.

Thanks to its hefty market share SKF has been able to grow gradually and build its infrastructure accordingly. All new knowledge is diffused throughout the company from engineers in Gøteborg, partly through their own production equipment. On the other hand, its information systems do not strike the observer as sophisticated or state of the art. Recently, however, SKF has increased its focus on customer service, having implications for its infrastructure. Ford, for instance, wants SKF to access their stock control systems twice a day to figure out their needs for bearings. Unitor, distributing bearings (among other products) to ships, requires SKF to deliver any bearing at any harbor within 24 hours and easy access to SKF's technical expertise (which means using modern telecommunications). They have also expanded their product portfolio to cover huge integrated systems for monitoring the bearings in large installations like oil refineries and motor plants. These systems are monitoring each bearing in these installations and are linked to the SKF engineers' computer systems in Sweden in case they need to intervene. These examples indicates that learning in general, and in particular in collaboration with customers is becoming more important. Most probably, SKF will have to adapt its current computing and organizational architectures. This might, however, be difficult as they both appear to be in a state of lock-in. The complexity of and interdependencies between their well running information systems constitute a robust infrastructure hard to change. Furthermore, their knowledge base is, to a large extent, embedded into work routines inscribed into systems, formalized into data bases, and wired into the infrastructure. The integration taking place over the past 20 years can be regarded as the internal enactment of standards now facing a huge lock-in challenge.

3.2 Roche

Roche, the sixth largest pharmaceutical group in the world, operates in four main sectors: pharmaceutical (58% of sales), diagnostics, vitamins and fragrances. Total sales in the first half of 1998 have reached 12,532 million Swiss Francs. R&D expenditures amount to 14% of sales. In Pharmaceuticals, the main therapeutic areas range from infectious diseases to oncology, central nervous system, and transplantation. Customers include hospitals, drug wholesalers, patients, and consumers.

The pharmaceutical industry continues to restructure in a highly fragmented market and is characterized more than ever by alliances, mergers, and acquisitions, followed by cost cutting exercises to face mounting price pressure, externalization of different activities, and intensified competition fueled by rapid innovation. The deployment of IT and process infrastructures takes place in such a turbulent organizational context, and cannot be considered in isolation from it.

But, despite the increasing scope for IT and process platforms being installed or developed, no coherent infrastructure seems to emerge. The infrastructure considered is the new "backbone" of Strategic Marketing: it is based on Intranet/Internet and does not contemplate any tightly defined business process support.

Marketing a pharmaceutical product is "knowledge intensive," as are most other activities in a pharmaceutical company. Knowledge is created in developing a new product; it emerges from the clinical trials and is consolidated in new drug application; more knowledge is acquired and processed, once the product is in use. It comes from various sources, inside and outside the company, and is continually gathered, processed and communicated throughout the product life cycle. Strategic Marketing sifts, filters, accumulates, and distributes the knowledge necessary to market a product world-wide. Strategic Marketing can only intervene in and influence indirectly the local marketing activities, namely by providing the background knowledge that is essential to carry out marketing in each country. Such knowledge has many forms and supports: training on the product features; clinical tests information, both before the launch of the product and after; prescription strategies, etc.

The affiliates, in their turn, produce and utilize knowledge according to the idiosyncracies of national markets and institutions. Also, the more complex and new the product is, the higher the number of intervening stakeholders (hospitals, physicians, regulatory authorities, patients, associations) in the highly dispersed process of knowledge creation related to the use and medical/social impacts of the new drug. The implementation of the infrastructure has undergone two distinct phases, I1 and I2.

3.2.1 Phase I1

In the 1980s, the Strategic Marketing function championed the establishment of its first computer and communication network. The purpose of the network and its applications, named MedNet, was to support the new, centralized marketing function (Ciborra 1996). Specifically, MedNet was supposed to be aligned with the strategy of achieving higher levels of globalization by making the affiliates' marketing strategies more dependent upon headquarters policies. Management acted like a "blind giant": they invested resources without having full control over the technology.

The infrastructure was developed independently from corporate IT: there were severe competence shortages at the time when standard commercial solutions were not yet available. This slowed down development and lead to huge costs. In the affiliates, MedNet was being adopted lukewarmly because of its high costs and its excessively standardized content and format. After eight years of development, the acceptance of the main applications (consulting medical literature; accessing clinical trials data; office automation) was still lagging (with the exception of e-mail). Some affiliates were even developing systems of their own, on separate platforms.

Almost 10 years after its launch, MedNet was discontinued. Its negative aspects, especially costs, dictated its end. However, it survived as an underlying network infrastructure. What was phased out was the application portfolio: its knowledge content and format were so “locked-in” that most of its components had to be scrapped completely.

3.2.2 Phase I2

Today, the new infrastructure is composed of Web sites, conceived and developed by the units in charge of the different therapeutic areas. Within the marketing organization, a “therapeutic area” is a semi-autonomous team of highly skilled managers and staff who craft the main product marketing policies world-wide, and provide product know-how to the national affiliates.

With minimal coordination and direction, each therapeutic area has developed or is developing Web sites for internal and external communication. Style, approach, and contents may vary sharply for each team.

For example, the Intranet, or Pharma Business Web, contains pages ranging from safety data to sales aids to generic product information. Other marketing departments provide training material, new businesses up to pricing, epidemiology, or competitor information.

One striking feature of the Internet Web sites is their interaction with constituencies outside Roche. Namely, for some diseases, external groups such as associations, lobbies, doctors, and even individual patients exert their voice and have a relatively high degree of horizontal communication on the Net. Thus, some therapeutic areas have created sites directed to the public as part of a new marketing mix. Note that when MedNet was still in existence, the Internet had been kept at bay because of confidentiality concerns in a company known for its secrecy. But the Internet gained ground and ultimately won because its use is backed by scientific communities that crossed the firm’s institutional boundaries when they needed to exchange knowledge.

Variety of applications, contents and style is observed not only among therapeutic areas, but also among the affiliates, which to varying degree are developing their own national and product sites. The approach is highly “unregulated.” New, local initiatives are flourishing in ways that are loosely connected to the headquarters initiatives. This reflects the spirit of the “cultivating” approach. Basel sites represent the “seeds,” i.e., templates and content repositories, around which local initiatives develop fairly autonomously. The “Basel template” diffuses through unplanned local adaptations and applications. It is a process of “loose cloning” accompanied by local transformation and reinvention. Headquarters relinquish control, giving up the idea of any enforcement of standards. Promoting the Intranet is done by example, rather than by top down imposition, by choosing some contents (like latest news) that can only be found on the Intranet, and by word of mouth and free imitation, i.e., involuntary spillovers, rather than by “pushing.”

MedNet has constantly struggled to gain and hold users. The new infrastructure is having a different impact. For example, the public Aids-HIV Roche site had 500,000 hits in the first three months of existence. The Pharma Business Web, after two years of operation, boasts 15 web sites, containing more than 11,000 Web pages that are accessed over 8,000 times (hits) a day. Thus, a critical mass of users, positive externalities, and self-sustaining diffusion seem today within reach, thanks to a very peculiar “alignment” between the spontaneous, dispersed knowledge processes and a “hands-off” management approach.

4. A NEW FRAMEWORK

The current view of infrastructure regards it as "the foundation" of the information technology portfolio. The firm's internal IT infrastructure combined with the external infrastructures are reputed to be "as important for enabling business processes in the future as the traditional physical infrastructure of roads, store fronts, etc." (Weill and Broadbent 1998). Having this "foundational" character, infrastructure needs the constant care and sponsoring of senior managers, exactly as public, governmental funding proved to be essential for the development of public infrastructures. According to the management literature, this analogy between public and corporate infrastructures is self evident and compelling. However, our research project suggests it may be deceiving, or at least valid only in certain cases. Specifically, this logic can be traced in cases, like SKF, of slowly moving businesses, where knowledge about markets, products, and processes is fairly static, or evolving incrementally. It also characterizes industries with low margins and consolidated competitive positioning. However, cases of more dynamic, knowledge- based companies provide some puzzling evidence. For example, full backing from top management is no guarantee of immediate or long term success (e.g., Roche Phase I1) or fast implementation (SKF). A totally decentralized development process can actually lead to a self-feeding diffusion (Roche Phase I2).

Consider, then, two distinct conceptions of infrastructures and two different development paths (Dahlbom 1998).

The first is the one advocated by the current management literature (Weill and Broadbent 1998): senior management needs to invest in the infrastructure, which like buildings, machines, and locations, allows the firm to reach its business goals. The shared resources (systems, applications, databases, etc.) required to run the business become the corporate foundation that underlies the competitiveness of the firm. If the firm is a bundle of knowledge processes, the infrastructure supports their smooth running: thus, infrastructure is "below" and "knowledge " is above. Our case studies suggest that this vision, and the management maxims that it implies, holds for those companies, (like SKF) where infrastructure can be built slowly; strategies do not change swiftly and dramatically, so that alignment can be fine-tuned; and knowledge about processes, products, and markets has enough time to sediment and be formalized in procedures and databases or formal information systems, so that management can control and allocate such explicated knowledge in a detailed manner.

For the more dynamic companies, we submit that such a model of infrastructure needs, at least in part, to be *turned upside down.* In other words, it is not a tool (the infrastructure) that supports various business capabilities (knowledge), but the other way around: it is the diffused informal and tacit knowledge enacted by people and business networking, conversations, spillovers, etc., that provides a "public infrastructure" which can enact a favorable environment for the IT infrastructure to take off. In its turn, IT infrastructure is a loosely coupled system that favors those involuntary leaks and spillovers of the emergent business knowledge needed to adapt to changing business circumstances.

While in the former approach, infrastructure creates locks-ins through investments in "heavy," irreplaceable components; in the latter, infrastructure is "light," consists of knowledge, and its dynamic is largely outside anyone's control, through spillovers of knowledge that cannot be kept completely proprietary. To be sure, also in the latter, "emergent" infrastructure lock-ins are possible, but they are linked to key interfaces in software and cognitive barriers due to the influence of extant paradigms and formative contexts (Ciborra and Lanzara 1994).

The management agendas may vary dramatically as our cases studies report, and they can be successful even if they are different, for they uniquely adapt to the nature of the business (static vs. dynamic; knowledge poor vs. knowledge intensive). In SKF, centralized planning and investment in the IT portfolio; streamlining of systems with the business; the elicitation and systematization of business knowledge in the business processes; the relevant enforcement of property rights on systems, processes, and knowledge throughout the corporation are the main ways to build and manage the infrastructure.

In Roche, infrastructure emerges and unfolds as the by-product of interlinked and overlapping activities related to technology and the business, activities that cannot be governed centrally. Infrastructure is the outcome of continuous innovations, imitation processes, and adaptations that follow more the commercial and R&D dispersed initiatives rather than the centralized vision and investments of senior management.

Our typology is consistent with the dichotomy one can observe in the take off of public infrastructures as different as roads and bridges on the one hand and Internet on the other. While centralized government funding is vital in the former case, knowledge spillovers and local, decentralized adaptations are crucial for the latter. We submit that this parallel between different types of infrastructures at the industry or economic system level can be seen also in the micro economy of the corporation, where centralized funding polices should coexist with the decentralized, bottom up initiatives stemming from the business. Finally, our study suggests that insisting on the top down approach in knowledge intensive firms is bound to backfire.

5. CONCLUSION

Stimulating reflections concern the long term consequences of corporations investing in IT infrastructures in a dynamic business. Economic theories suggest that firms are hierarchical because of information costs, information asymmetries, and efficient trade-offs between direction and sharing of knowledge. Spillover effects, *de facto* looser property rights on corporate knowledge, the growing role played by knowledge itself as a public good and an infrastructure to run the business and create new ones—will they endanger the hierarchical structure of the firm? The knowledge infrastructure combined with the IT infrastructure reduces information asymmetries; multiplies involuntary spillovers and opportunities for freely recombining knowledge—indeed a scenario for the complete demise of the hierarchy? For sure, an indication to enrich the current infrastructure management agenda.

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