in: Journal of the Association of Information Systems (JAIS), Volume 10, Issue 5, May 2009, 306-332

Infrastructuring: Towards an Integrated Perspective on the Design and Use of Information Technology

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Abstract

In this contribution we investigate how results from the ongoing discussion about 'e-Infrastructures' can be used to improve the design of IT infrastructures in organizations. We first establish a perspective on organizational IT as 'work infrastructure' that focuses on the infrastructural nature of organizational Information Systems and describe challenges for designing within and for this type of infrastructure. Then we elaborate on possible use of concepts from the e-infrastructure discussion, in particular on the concept of 'infrastructuring' as it was developed by Star and Ruhleder (1996) and Star and Bowker (2002). Using their 'salient characteristics of infrastructure' we describe the methodological approach of 'Infrastructuring' to develop methodological and tool support for all stakeholders' activities that contribute to the successful establishment of an information system usage (equivalent to a work infrastructure improvement). We illustrated our ideas by drawing on a case in which new work infrastructures were introduced into an organizational context and by mapping out existing and possible tool support for 'infrastructuring'.

Keywords: Infrastructure, Infrastructuring, Design, Software Development, Information Systems

Introduction

In the disciplines of Computer Science and Information Systems, it is quite common to talk about 'infrastructure' when describing either the multitude and diversity of hardware devices, software applications and standards that modern organizations use in their everyday procedures in general, or sometimes one specific but crucial software application, e.g. an ERP system. In these approaches, the term 'infrastructure' remains underdefined, and it is unclear whether the use of the term implies other methods and perspectives than the use of e.g. 'artefact'. 'system' or 'network'.

But there are a number of developments in organizational IT practices that advise us to take the issue of infrastructures more seriously. The number of IT devices increases, they spread across more and more application fields (professional as well as private), wireless technologies keep them constantly connected to each other and together with all that the network of standards that guarantee a working network becomes more complex. At the same time, aside from technological issues, IT support becomes taken-for-granted in many professional and private use environments, and users and organizations become dependent on a certain quality of service of the IT they work with to an extent that requires to prioritizes the existing infrastructure over possible additional innovative applications.

In the field of Science and Technology Studies, the term 'infrastructure' has been used to highlighten these aspects of Large Technological Systems (LTS), namely the role of standardization, dependencies and emergence from a previous base (e.g. Heinze and Kill 1988 about the German railway system, Hughes 1983 on the development of electricity infrastructures, 1983, La Porte 1988 on the US Air Traffic System). Closer to the field of Information Systems, the emergence of the Internet itself has also been studied e.g. by Abbate (1994). Focusing on a sociotechnical perspective (i.e. looking at physical entities as well as the role of actors), several conceptualizations emerged (Hughes 1983, Star and Bowker 2002) that contributed to a better understanding of emergence, inheritance and appropriation processes in Large Technological Systems.

The discourse has in general a straightforward relation to the field of Information Systems: The network of interconnected devices visible (computers, etc.) and invisible (internet backbone cables and routers, etc.) to the users that operates on the basis of standards (Tanenbaum 1996) and other networks (e.g. electricity) easily qualifies in any definition as an 'infrastructure' for individuals, organizations and the society as a whole. The sociotechnical perspective on their development matches the general understanding and methodology used in the field of IS (Mumford 1987, March and Smith 1995, Hevner et al. 2004). But there are only few approaches that try to make use of conceptualizations from the 'infrastructure' discourse in STS (Star and Ruhleder 1994, Hanseth et al. 1996, Ciborra and Hanseth 1998, Hanseth and Lundberg 2001, Bleek 2004, Karasti and Baker 2004). Most of these approaches use the concepts around 'infrastructure' as an analytical lens to highlight important issues in around using information systems. In this contribution, we want to use these concepts to develop a framework for *designing* organizational information systems that focuses on the role of IT as a 'work infrastructure'.

IT-based work infrastructures

Our understanding of modern work environments is that they mainly use information systems as an infrastructure for work, these become 'work infrastructures'. This notion is connected with the baseline of the infrastructure discussion in STS, and we want to highlight with that term certain 'infrastructural' aspects of information systems that we consider particularly relevant:

- *Interconnectedness and complexity*: In modern work environments, even in 'simple' cases of office work, use IT in many interconnected forms like desktop computers, software (applications, databases, etc.), in- and output devices, servers and IT based communication facilities (IP telephony, mobile phones, etc.). Together with 'background' devices like routers or name/domain servers in the organization and the general Internet infrastructure outside the organization they form a network of network that however local its usage is, remains a global infrastructure.

- *Layer approach and Standardization*: To manage the complexity, a number of technology layers emerged (e.g. in the area of computer networks Local Area Networks, organizational Intranets, national network infrastructures, the global Internet) that, however 'far' away from the workers' computer as an 'infrastructure outlet', may have various immediate effects on the worker's choices to proceed with his work. The layers interoperate by abiding to standards, and it is important to note that while some standards (and transition processes to a new standard) remain in the background of the work environment (e.g. moving from IPv4 to IPv6), others are highly specific for certain usages or devices (e.g. when synchronizing data between contact databases on a desktop computer and a mobile phone).
- *(In-)Visibility in use*: In most work environments, workers use the infrastructure all the time, but they rarely are aware of that after the IT devices and applications have become an integral part of the work practice. As long as the technologies serve the purposes ascribed to them, they remain invisible to the user, but once they fail, the dependencies between work tasks and IT tools make the infrastructure failure the primary concern of workers.

The relevance of these dimensions for developing IS design methodologies are only partially obvious. Design methodologies require to define a scope of design (e.g. one device or software artifact) which also means to define what is 'internal' (things to modify/design) and what is 'external' (issues to 'consider') of a design process. Parts of the 'work infrastructure' will be (and need to be) excluded, but the complexity of the work infrastructure makes this a difficult and error-prone process where corrections may be necessary later. This decision remains often implicit and is usually also not part of a design methodology. Similar dynamics develop in the use of standards that define the technological fit between the newly designed devices/technologies and the existing technological base. Implicitly there is a decision which standards to ignore (as they are not relevant), consider (as they represent anchors for the new technology in the existing infrastructure) or newly integrate (as they guarantee the functioning and/or expandability of a new technology) into the work environment when designing a new technology. Corrections may be necessary for conceptual (e.g. incorporating stronger encryption standards due to changed risk considerations) or pragmatic (e.g. because existing technologies do not fully comply to standards) reasons. The (in)visibility of a work infrastructure makes it hard for users to be fully aware of their own work procedures, making it difficult for designers to elicit requirements, and making it more likely that a technological solution needs several iterations of evaluation and design improvement until it is considered useful. On the other hand, technological failures may produce significant problems in work environments making a redesign a very urgent issue of designers as well as users, and making visible (clarifying/raising awareness for) dependencies that may have not been very present before.

This brief discussion makes clear that the term ‘work infrastructure’ helps highlighting aspects of design methodologies that have to less with the interior organization of designers/developers in a deign process, but more with the embedding of the technologies to design as well as the process itself in an existing work environment.

But we would also like to point out where we believe information systems to be a very special type of infrastructure with a set of problems and opportunities that can’t be found in traditional infrastructures. Considering information systems as ‘work infrastructures’ that transport and distribute ‘information’ (analogous to the distribution of electricity or water in other infrastructures) relevant for work environments, we consider the following characteristics as specific:

- A *unique versatileness*: The infrastructure can be used for many purposes in many work environments, and parts of its success can be attributed to the ability to combine multiple purposes into one technology or tool even across spatial, professional and organizational boundaries that previously could only be achieved by using multiple tools.
- *Reflexivity*: Information Systems as ‘work infrastructure’ can be seen as being reflective in two ways: The work environments of technology designers are part of the same global infrastructure as the technology users, and all improvements of the

global infrastructure are being developed within that infrastructure. And, more fundamentally, large and important parts of that infrastructure (i.e. software) can be processed within the infrastructure like ‘information’, which has beneficial (e.g. the opportunity of automatic improvements in the form of software updates) and problematic (e.g. software viruses) consequences.

Again it is a challenge to IS design methodologies to cope with the consequences of these aspects. The aspect of versatileness adds to complexity issues mentioned above, but may be too broad to influence design methodologies in a direct way. Rather, it accounts for opportunities of technology users to modify and appropriate different parts of the infrastructure in ways unforeseen by the technology designers. We consider two cases: a new tool in a work environment may be used in a way not intended by designers, but users may also choose (a combination of) other available tools over a newly developed tool to serve the purposes it was designed for. It remains a challenge to design methodologies to integrate both possibilities methodologically. The aspect of reflexivity allows new ways of organizing design. In designing information systems as ‘work infrastructures’, it is possible to choose different compromises between design-before-use and design-in-use than in most other types of infrastructures. It is also possible to forge different types of collaboration between designers’ and users’ work environments. Recent tendencies around issues like User-generated content, end-user development and Web 2.0 indicate, that within the infrastructure different and dynamic divisions of work are possible and useful in the development of information systems.

We expect the use and appropriation of the terminology developed in the STS discussions around ‘infrastructure’ to highlighten the IS/work infrastructure aspects described and develop a framework for infrastructure-aware design methods here.

We briefly would like to mention similar approaches to ours. Hanseth and Lundberg (2001) developed the notion of ‘work-oriented infrastructures’. They were also driven by an understanding of collaborative Information Systems as infrastructures and derived from an inspiring case study in a hospital's radiology department basic recommendations for the design of work-oriented infrastructures:

- users will inevitably drive the shaping of a new infrastructure during use, and should always be considered as 'designers',
- new technological systems have to carefully map all aspects ascribed to the artifact and activity chains that operated on the 'old' (maybe non-digital) infrastructure.

Consequently they do not speak of information system design as the main process to consider, but of 'infrastructure improvement'. In that respect we share their perspective, but we want to derive stronger methodological implications for design.

In our context, we will subsume all activities that contribute to a successful establishment of usages under the term 'infrastructuring' to avoid confusion with classic notions of 'design' as design-before-use performed by professional designers. To derive stronger methodological implications, we now first elaborate on the theoretical background for the development of our perspective. We then describe our framework and its terminology, and show some examples of how our framework helps developing infrastructure-oriented perspectives on all activities in application fields that contribute to the successful establishment of a usage as well as examples on concrete prototypes that respect an infrastructural perspective.

Organizational Information Systems between 'Design' and 'Infrastructuring'

The design of information systems for organizations has always been confronted with the 'infrastructural' aspects we described above. We now briefly outline the coping approaches inscribed into design methodologies, followed by a description of the discussions around 'infrastructure' and its involvement with informations systems so far. We then revisit our construct of 'work infrastructure' to refine the challenges our framework is supposed to answer.

Coping with infrastructural aspects in information systems design

To make our approach to interpret informations systems as 'work infrastructure' plausible, we described the importance of several 'infrastructural aspects' of modern work environments respectively the information systems being used there: Interconnectedness/Complexity, Layers/Standardization, and Invisibility during use. We also described which design problems relate to these aspects: Choosing the right section of the existing infrastructure for consideration/modification during design (interconnectedness/complexity), organizing the relation between aspects interior to a design process and aspects outside by means of standardization (layers/standardization), and finding out/managing current and potential relations between the technological entities and their use practice (invisibility during use).

In the very first approaches to organize IT development processes, these aspects were marginalized since the 'software crisis' acknowledged in the late 1960s was perceived as a problem of the interior organization and systematization of development, and answered by systematizing process approaches like the waterfall model (Royce 1970). The first failures of large software projects gave an impulse for further developing the methodologies.

Incremental and iterative design methodologies

After analyzing failed software projects, Boehm (1988) introduced 'risk management' as an important factor for IT development methodologies and created an iterative approach that frequently revisited the design problem to analyze whether the design activities still target what is relevant in the work environment. Similar approaches developed with different notions (Floyd et al 1989 with a focus on integrated user participation; Henderson Sellers and Edwards 1990 with a focus on the object-oriented programming paradigm). Today we find refined methods with different strengths (e.g. the process-centred 'Unified Software Process', Jacobson et al. 1999, and the more comprehensive and more formal Capability-Maturity-Model, CMMI, Paulk et al. 1995 and Ahern et al. 2001, that covers all organizational aspects of IT development). The focus on the internal organization of the design remains, but the methodologies showed a pragmatic approach to deal with the design issues of the infrastructural aspects described by frequently revisiting and revising the basic decisions that have been made earlier in the design process.

Organizing user participation

The second trend in IT development methods was to integrate the users in the design process to be able to identify potential conflicts and misalignments of the newly designed part of a work infrastructure with its existing technological and social environment more effectively. The 'integration' approaches reach from (in a wider sense) ethnographic methods (e.g. STEPS, Floyd et al. 1989; Use Cases, Jacobson et al. 1999; Contextual design, Beyer and Holtzblatt 1997, many approaches in Requirements Engineering, e.g. Robertson and Robertson 1999) to approaches where users actually participate in design decisions (e.g. Bodker et al. 2004). User participation also is a pragmatic approach to change design methodologies in order to manage issues of complexity and standardized interfaces between new and existing work infrastructure. It's approach to make users stronger aware of the technologies they use, and to motivate them to contribute to a design process, also addresses the third infrastructural aspect 'invisibility in use'. It also marks the step from a disconnected engineering perspective to a socio-technical perspective on IT development (in the spirit of – and at least in parts inspired by - Mumford 1987).

Supporting and Organizing Design-In-Use

With the third infrastructural aspect we described a remaining practical problem is highlighted that could not be completely overcome by user participation: Capturing and discussing projected usages; from a 'participating' user perspective that means to imagine and communicate technology usages where the actual use of a tool has sunk into the background of user considerations at use time. The work spheres of professional designers and potential users remain separated: On the one hand, in a participatory IT design process the designers usually decide that it is 'design time', while the user has problems allocating time for an additional task within the daily work routine, and difficulties in explaining expectation to an unknown work practice using a new technology. On the other hand, when a certain technological improvement occurs to users during use, it is not necessarily 'design time' for professional designers.

Approaches like STEPS (Floyd et al. 1989, and even more its refinement 'Integrated organizational and technology development' by Wulf & Rohde 1995) extended into the use phase during the design process iterations to answer this challenge, and replaced the traditional IS design notion that design precedes use by a notion that a finalization of the design happens in-use. Particularly in IT domains where the 'social' aspects dominate the 'computational' aspects of computer support, e.g. collaboration intense applications such as groupware, studies showed that it may not be appropriate to strongly enforce such a clear separation (Mackay 1990; Nardi 1993; Wulf and Golombek 2001). Therefore, Henderson and Kyng (1992) suggested to 'continue design in use' in order to enable users to detect and configure relevant aspects of their work infrastructure. As a consequence, highly flexible Information Systems have been suggested to allow adaptation ('tailoring') of technology to new or changing requirements at use-time (Henderson and Kyng 1992; Malone, Lai, and Fry 1992; Wulf, Pipek, and Won 2007). The discussion resulted in the paradigm of 'End-User Development (EUD)' (Lieberman, Paterno, and Wulf 2006) where these approaches were merged with earlier research on 'adaptive computing' or 'end-user computing'. The question marks that remain in these approaches circle around issues like the computer literacy of users and the time constraints under which users have to perform in-use design.

'Infrastructural challenges' to IS design

In our account of the development of IS design methodologies, it becomes clear that these indeed can be interpreted as 'coping approaches' with 'infrastructural aspects' of information systems. While the approaches show creativity and a variety of perspectives on IT design, they remain more a quilt than a solid fabric that captures and supports all aspects and activities relevant to establish successful IT usages.

It is particularly the creativity of the users that remains unaccounted for. With an infrastructure perspective, the fringes of professional design come into focus. Considering our own experiences from long-term studies on collaborative information systems (Pipek and Wulf 1999, Törpel et al. 2003, Pipek and Wulf 2003), and considering infrastructure-oriented studies from Hanseth 1996 and Hanseth and Lundberg 2001, we believe that the strict separation of design and use that is maintained on a methodological level is one of the core problems of IS design methodologies. The term 'design' may even be already misleading as it focuses on an artifact that should be designed, and neglects the surroundings the artifacts is placed into, which again are what is in our focus when we discuss 'infrastructures'.

The experience with Tailoring and End-User Development (Liebermann et al,. 2006, Fischer 2002) showed that indeed different degrees of technological expertise are involved in using and developing infrastructures. But these are not permanently bound to certain professionalization structures, but can also emerge with simple users when coping with infrastructural problems. Suchman (2002) analyzed problems in software development regarding the production systems of technology and use, and particularly the structures of professionalization in design. In her eyes, professionalization often leads to assumptions and processes that do not respect the true (from a user's perspective) nature of the design problem and that ignore possible alternative solutions. She pointed out that the phenomena of 'design from nowhere' (professionals assuming a comprehensive ahistorical yet external perspective) and 'detached intimacy' (professional searching for skill development within their community while maintaining a distance to their customer communities) should be considered as opportunities to develop into new forms of collaboration between different spheres of professionalization that respect the 'located accountabilities' of technology production and use. The principle of 'Artful integration' addressing the cultural production of new forms of material practice, is helpful since it accepts the necessity of and the support for 'partial translations' (Suchman 2002). Artful integration shifts the view on knowledge from an objective, privileged, asituated, property of professional masters, towards one of multiple, located, partial perspectives supported by ongoing processes of negotiation. This crucial role of knowledge exchange and negotiation in design is echoed in the critical analysis of the CMMI of Nielsen and Kautz (2008).

Where traditional IT design approaches focus on the artifact, the skills of designers, defined information interfaces between design and practices to support, and the general effective organization of design work, the infrastructural aspects we described demand for opportunities to renegotiate the border between what remains and what is being changed when designing information systems, to renegotiate who changes aspects of information systems, and to renegotiate when these aspects are changed (before or during use). Terminologies from the discussions around infrastructures in STS provide approaches and terminologies that reflect these aspects.

Infrastructure and Infrastructuring

There are several naïve approaches to understand information systems as infrastructure. Tanenbaum's (1996) description of computer networks or Dourish's description of collaborative infrastructures may serve as examples of a techno-centric understanding of IT infrastructures. In the research on information systems, these are often understood as organizational infrastructures without actually clarifying this concept sufficiently. Theoretical approaches as well as empirical studies looked at the organizational effects of the implementation of Information Systems. However, the relationship between IT and organization was often interpreted only as taking the opportunities IT offers as a starting point for organizational change (Crowston and Malone 1988). For instance, Shaw (2002) argued for the importance of the structure of technology for understanding the complexity and effects of changes to an organizational infrastructure and provided a model to differentiate the Technology Acceptance Model (TAM, Davis 1989; Venkatesh and Davis 2000). McGarty's (1992) understands 'infrastructure resources' to be shareable among users, common, enabling, physically embodied, enduring, scalable, and economically sustainable. Hanseth (1996) rightfully criticizes such an understanding because it requires too much homogeneity, it is only suitable for closed systems, and it does not involve any non-technological aspects. It is common to these approaches, that 'infrastructure' is treated as 'technology in context' with organizational and societal aspects covered as 'context'.

Learning from the history of infrastructures

As Van der Vleuten (2004) pointed out, a very early interest in the structures that keep a society running already developed in the 17th century, when e.g. Petty in his 'Political Anatomy of Ireland' in 1672 described tradesmen as playing 'the role of veins and arteries' that nourishes the organs of a national economy. Similarly, in warfare a clear understanding of the value of stable, reliable transportation means (consisting of devices like cars and ships and structures like roads and waterways) emerged that treated the management of this background work behind the lines a key success factor (Ratzel, 1897, cited in Van der Vleuten, 2004).

In the 1980s a growing research interest in a combined analysis of the 'social shaping of technology' and the 'technological shaping of society' (Bijker 1995) resulted in a number of systematizations of the emergence of infrastructures. Hughes (1983) analyzed the history of electricity infrastructures and identified as key factors in infrastructure development system builders (the people that develop, implement and maintain a technological system), momentum (directed and relatively continuous movement of infrastructure development and use), load factor (ratio of average system output and maximum system output), and reverse salients (parts or aspects of an infrastructure that build an obstacle to its further development, e.g. bandwidth in the Internet).With regard to their emergence, Hughes (1987) distinguished the phases Invention, Innovation, Technology transfer, Growth, Competition and Consolidation, in which different states and organizational settings (including actors) of a new infrastructure can be distinguished. Heinze and Kill (1988) described the emergence of the German railway system and distinguish the phases 'invention and isolated introduction' (local city links installed), 'demand-oriented construction' (further cities integrated, usually along the lines of business interests), 'supply-oriented extension' (almost all cities integrated as a national act of solidarity) and 'maintenance-oriented cut-back' (thinning out non-profitable routes, also considering competing infrastructures like roads). In his description of the US air traffic system, La Porte (1988) pointed out, that the (non-)physicality of an infrastructure leads to additional degrees of freedom whose regulation needs to be negotiated and acknowledged by all actors (e.g. air traffic routes). By analyzing and discussing the emergence of infrastructures, these systematizations cover aspects of design, but do usually not account for actual activities of the stakeholders involved. The discussions are certainly inspiring for reconceptualizing information systems in terms of infrastructure (see below), but the lack of a focus on activities makes it very difficult to apply these systematizations as a foundation for design methodologies.

E-Infrastructures and Information Systems

Some more recent research in Information Systems referred to the STS discourse under the topic of 'e-Infrastructures' to improve our understanding of the processes of evolving technological dependencies, for commercial (E-Business) as well as scientific (E-Science/Cyberinfrastructure) application environments (Star and Ruhleder 1996, Törpel et al. 2003; Atkins 2003; Finholt 2004; Karasti and Baker 2004; Karasti and Syrjänen 2004; Lawrence 2006; Ribes 2007; Zimmermann 2007). The discussion sprung from an older discourse on mutual influences in developing large-scale technological infrastructures (Edwards et al. 2007).

While all contributions used some concepts of the STS discourse, Star and Ruhleder (1996, later rephrased in Star and Bowker 2002) were the only ones who provided a systematization similar to the ones provided in other studies of infrastructures. In their analysis of a distributed information system that serves a scientific community as a platform for archiving and exchanging data they described eight salient characteristics of infrastructure:

- the embeddedness of infrastructures in other social and technological structures;
- the transparency in invisibly supporting tasks;
- both, the spatial and temporal reach or scope;
- the taken-for-grantedness of artifacts and organizational arrangements learned as part of membership;
- infrastructures shape and are shaped by the conventions of practice;

- infrastructures are plugged into other infrastructures and tools in a standardized fashion, though they are also modified by scope and conflicting (local) conventions;
- infrastructures do not grow de novo, they wrestle with the inertia of the installed based and inherit strengths and limitations from that base;
- the normally invisible infrastructures become visible upon breakdown.

This definition stresses the socio-technical relations in the sense that infrastructure should always be seen in relation to organized human 'doing' and being interwoven with social systems. It develops a perspective on infrastructure not as something that 'is' an infrastructure, but as something that is being perceived as infrastructure by its users. It also connects a 'global' view of a wide-spread technological infrastructure with a 'local' view of its use. Contrary to other systematizations, it also covers aspects that relate to activities of users ('learned as part of membership' implies user learning about the infrastructure, 'conventions of practice' implies user negotiations of conventions). It allows connecting a perspective of infrastructures as 'developing phenomena' (a macro perspective) with a perspective on infrastructures as 'embedded in and supporting networks of concrete activities' (a micro perspective), and thus opens up the opportunity for creating a level playing field for addressing all actors and interests relevant for a successful establishment of an IS usage. We will later explore its potential to serve as a foundation for an infrastructure-oriented design approach.

Later, Star and Bowker (2002) used the systematization also in a broader description of cases of information systems interpreted as infrastructure. The title 'How to infrastructure' stressed a focus on 'doing' and lead to the exploration of 'infrastructuring' as a more comprehensive term for the creative 'design' activities of professional designers and users (Karasti and Syrjänen 2004, Karasti and Baker 2004, Pipek and Syrjänen 2006), which we will continue in this contribution. Star and Bowker describe as implications for design of their survey the need for backward compatibility and modifiability of infrastructures, and the need for tentative, flexible and open design processes and users who are aware of the political and social work an infrastructure is doing.

Underexplored issues in e-Infrastructures

In an ICT-based infrastructure, there is an additional level of reflection support possible that traditional infrastructures could not provide. Information systems can form reflective infrastructures that offer infrastructural tools to mediate their own further development. The possible ubiquity of information and communication (which describes in our eyes more accurate what makes Weisers vision of 'Ubiquitous computing' from 1991 so important) allows e-infrastructures to provide representations of its inner workings as well tools for discussing, negotiating and modifying it. As the space for these options opens up, traditional competence/skill profiles and professionalization structures that are both, assumed as well as inherited, become more permeable, which allows as well as requires new methodological considerations (e.g. with regard to different divisions of workbetween professional designers and users). With the notion of reflective infrastructures, our discussion goes beyond the experiences described in the analyses of non-IT infrastructures.

Work infrastructures revisited: The design challenge

We now discuss the informal interpretation of 'work infrastructure' in some more detail. We briefly revisit infrastructure-oriented approaches in IS and define our understanding of work infrastructure, we clarify commonalities and differences with the infrastructure approaches in STS, and we develop design challenges we aim to meet.

Definitions of work infrastructure

With regard to existing approaches in IS, we don't find many characterizations of infrastructure. A citation from Ciborra and Hanseth (1998) may be a quite good illustration of the use of 'infrastructure' in IS:

"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)."[1]

From our point of view, the crucial question is: who is involved in 'managing an infrastructure'? While in IS the traditional thinking addresses the management to be in charge of the organization of work, the discussion on E-Infrastructures deals with the complete innovation chain that brings infrastructure usages 'into effect'. Obviously, there is need for and articulation of professional technological expertise and management within the creation processes of an infrastructure. However, there are also processes 'in between' concrete product design, e.g. standardization issues, and processes of developing or discovering usages and their effects on individual end users as well as on the society as a whole.

Hanseth and Lundberg (2006) develop their understanding of 'work-oriented infrastructures' from such an understanding of 'infrastructure':

"When approaching information infrastructures we focus on four aspects. Infrastructures are shared resources for a community; the different components of an infrastructure are integrated through standardized interfaces; they are open in the sense that there is no strict limit between what is included in the infrastructure and what is not, and who can use it and for which purpose or function; and they are heterogeneous, consisting of different kinds of components – human as well as technological."

While the authors do not further describe or differentiate 'work-oriented infrastructures' they treat them implicitly as infrastructures supporting (collaborative) work, in their case work of a hospital's radiology department.

A more elaborated conceptualization of IS design in relation to the issue of infrastructures is presented by Hanseth and Lyytinen (2004). Their description of a design theory for 'Information Infrastructures' focuses on the designer's perspective in establishing an infrastructure. In contrast, we see the designer as one of many roles involved in an inevitable

[1] Original citations preserved.

(and consequently not mainly design-driven) process of developing infrastructures that is driven by tensions resulting from infrastructure breakdowns and use innovation. In our eyes, an infrastructure-oriented perspective on IS design needs to focus on mapping actors and activities acknowledging their contributions to infrastructure development, and to advise the roles that can be identified with regard to methodological issues.

From our point of view, the 'work infrastructure' of a worker or organization is the entirety of devices, tools, technologies, standards, conventions and protocols (in a broader sense) that the individual worker or the collective rely on to work on the tasks and achieve the goals associated to them. The elements are interconnected mainly in two ways: Either in a technological sense that the functioning and usefulness of elements is dependent on the functioning of other elements, or on the basis of use-based ties that are motivated by a shared interest of users, a shared organizational aspect (work task, department, etc.). Dependencies may be transitive (see Pipek and Kahler 2006 for a more detailed discussion on use-based ties). While our general definition does not exclude non-IT devices, we consider IT devices and technologies to play a crucial role in the ensemble of tools and technologies. Consequently, workers are assumed to have a variety of skills of using and improving work infrastructure that relate to Information Technology. Actors in processes of work infrastructure improvement may be professional IT designers, but basically we consider everybody an actor in these processes that performs a conscious, creative activity that is directed towards what s/he considers an improvement with a lasting effect. We attribute to work infrastructure also all of Star and Ruhleders (1996) characteristics of infrastructure. We now discuss some other aspects that are specific for our perspective of work infrastructure.

A differentiation of the dimensions of notions of infrastructure

There are several dimensions attributed to earlier uses of 'infrastructure' that we need to relate to: Issues of size/globalness/localness (work infrastructures may not be global, but on various levels of globalness), issues of longevity/sustainability (work infrastructures last long in relation to the work tasks they support, but may still have a significantly shorter lifetime than classical infrastructures) and the issue of incorporating people as infrastructure.

Infrastructure is often considered as a large technology-shaped network structure of connection channels together with the related devices, appliances, machines or vehicles that allow using them. But how important is 'large' as a characteristic of infrastructure? We may consider modern railway transportation networks as an infrastructure that spans countries and even continents, but how important is that to a commuter who lives in Bonn and works in Siegen, about 60 miles away? How relevant is this size for a company that plans setting up a transportation service between Bonn and Siegen? How relevant is the sheer size for an engineer who aims at providing train-based mobile phone services along a track that has as many tunnels as the track between Bonn and Siegen? We believe that the concept of an infrastructure in its technological as well as in its social meaning is useful independent of the artifact's sheer size. Restricting the notion of an infrastructure to the local transportation service between Bonn and Siegen allows maintaining the perspective on work activities and environments with regard to the design of services as well as with regard to the train's use (although, of course, there are indirect effects resulting from scaling issues). For some IT applications it is often not quite clear whether they will be used as part of a 'large' or a 'small' infrastructure. The use of an Internet Browser may usually be connected to browsing the global web, but its use can also be very local when browsing HTML documents on the local hard drive only.

From address books, calendar databases or reference libraries we collect important information. While these IT applications are small and local from a technological perspective they largely inform or hinder our orientation in the scientific work context and have become indispensable for our work. We also expect 'side artifacts' such as calling cards, university department flyers, or paper hand-outs to be important for an efficient work organization. Here, small and local technologies address a kind of 'Infrastructure' that does not necessarily have a technological manifestation but more a cultural nature. Nevertheless, dependent on the level of 'taken-for-grantedness' and implicitness for work these cultural rituals develop, they may become as tangible as technological structures in a work environment. We believe that it is not the technology in itself that has to be 'large' or 'global', it is rather a certain usage or a ritual when using it that defines the level of 'globalness'.

Adding to the previous issue, we can further question a techno-centric notion of infrastructure with regard to the mutual dependencies between the social and the technological spheres. As Hanseth (1996) described, the Clinton/Gore administration – in addition to several technological aspects - also subsumed 'people' as part of their plans in developing a 'National Information Infrastructure', people that help designing, configuring and using it. It is obviously not absurd to consider people who help others accessing and appropriating a technology as a part of its infrastructural nature. Observing practices with regard to work infrastructures, we often see that users who specialize on using technologies are regarded as 'technology experts' by their colleagues (cf. Nardi 1993; Pipek and Wulf 1999). To a certain extent, these users (by means of their education, training, communication skills and experience) become 'social infrastructures' in work settings that significantly contribute to establishing technology usages.

One other important aspect of infrastructures that is often mentioned is the issue of longevity, stability and sustainability (e.g. Ribes 2007; Zimmermann 2007). While 'the internet' can undoubtedly be seen as an infrastructure that will last for quite some time, its material foundation has completely changed over the last 15 years. The resulting changes regarding bandwidth and speed became relevant in organizations e.g. with regard to acceptable sizes of e-mail attachments and website content. The local 'access points' like browser and e-mail clients have changed not so fundamentally with regard to the functions they offer. However, what kind of products companies and users consider to be their 'infrastructure' in accessing the Internet may change quite frequently depending on extensibility or security concerns. This illustrates that in organizations, different layers of infrastructure may be connected with quite different expectations regarding durability, and that the users' perceived stability is more important than the actual stability for using the same network wires and devices.

Design in work infrastructures

In this section we discuss what difference it makes to think about design in work infrastructures from an IS perspective. Although design methods in IS have improved with regard to the 'technology fit' with users' needs, they are still inherently based on a perspective which focuses on the designers to be the main actor in developing IT infrastructures. Their way of infrastructure improvement is always confined to (re-)design competencies with regard to the IT product under consideration. The users' perspective on developing the IT infrastructure is, however, broader. It also involves the transition from old to new routines and usage patterns, and it is more diverse. While product-related choices in the application domain may present a unanimous picture to the designer, any organizational unit and any individual actor confronted with such an infrastructure has to find their own ways of integrating the technology into their work practices. So, new functionality may only be partially perceived and integrated into the users' practices, for instance applying just the 'cancel red eye effect' function of a powerful image manipulation software. It may also lead to a parallel usage of alternative technologies for the same purpose, for instance using an old and a new version of a software for compatibility purposes or using different internet browsers for private and business-related web surfing. Sometimes, the development of usage patterns also goes beyond the usage intended by the designers. Orlikowski (1996) mentions in a study on Lotus Notes how a commentary field of a helpline case management database was used by the call center staff for communicating about dealing with specific cases in a chat-like manner. These dynamics are addressed in the research about IT adoption or IT appropriation (Orlikowski 1992; DeSanctis and Poole 1994; Pipek and Wulf 1999; Pipek 2005), but they have rarely been captured on an activity level, which would be necessary to derive a methodological consolidation needed for integrating this research with research on IS design methodologies. In our eyes, the term infrastructure and the research conducted around it provides a good foundation for integrating designers' and users' choices in developing an organization's information system. It allows deriving a more comprehensive perspective on the different contributions made by designers and users and ultimately enabling us to enhanced 'design' methodologies.

A framework for 'infrastructuring'

Working on the improvement of work infrastructures is a creative activity that can be described as 'design'. For the scope of this contribution, we understand 'design' as any motivated, transformational activity that individuals or groups perform. 'Motivated' means that every design activity has a goal or at least an intention. 'Transformational' means that it induces a change that is intended to have a longer-lasting effect. Although for the scope of this paper the 'changes' we address refer to programming, configuring and using collaborative infrastructures, we want to remain open with regard to other design domains.

We also use the term 'infrastructuring' to distinguish ourselves from notions of design that only refer to professional, or better said, professionalized 'design' activities. It is the degree of professionalization with regard to (technical) competencies that leads to the distinction between 'users' and 'designers'. Based on this distinction, traditional design methodologies in IS priorize the designers' perspective in a way which obstructs the perception of the users' contributions to the improvement of infrastructures. Taking the concepts of infrastructure and infrastructuring as defined above, we now develop an integrative perspective on activities that contribute to infrastructure improvement.

Distinguishing activity spheres by work purpose

Although we want to put the classical 'design' activities of professional designers and creative 'appropriation' activities of users behind us, we need to distinguish two activity spheres that relate to each other. The first activity sphere (usually associated with 'users') consists of all creative activities around the improvement of an individuals or an organizations own work practice, regardless of the purpose or goal of work. The second activity sphere revolves around the first, if they target the same work practice: It consists of all creative activities that contribute to the improvement of somebody else's (individual or organization) work practice, where this contribution is the main work purpose or goal. In

Figure 1 these spheres are already specialized for information systems as work infrastructures: The lower half represents some organizational practice as the first activity sphere (called ‘work development activities’), the upper half represents as the second activity sphere the creative activities of professional designers whose purpose it is to improve the same organizational work practice.

Distinguishing the Whens of design: The ‘point of infrastructure’

The next consideration addresses the question ‘When is design (time)?’. Although we want to address all creative activities that contribute to the successful establishment of a technology usage, there are different modes of awareness for these infrastructuring activities. We define as a demarcation line the ‘point of infrastructure’ which is exactly at the moment an infrastructure becomes ‘visible’ to its users. Using the terminology from the STS discourse discussions around infrastructure we distinguish two reasons for that: an infrastructure breakdown and the local resolution of a reverse salient (which we refer to as ‘innovation’). During a breakdown scenario the users become aware of an actual or perceived ‘breakdown’ of the infrastructure in the sense of an insurmountable incongruence between the expected service and the actual or perceived behavior of the technological infrastructure. The second (more ‘positive’) moment is a ‘use innovation’, when a new technological infrastructure gets appropriated for a local context. Star and Bowker (2002) describe this phenomenon as ‘resolving the paradox of demassification’. The opportunity offered by a ‘global’ technology (technological infrastructure) is met with the creation of and a decision for a new ‘local’ practice. It is important to note that in our description a ‘breakdown’ can be initiated either from the ‘technology side’, e.g. when part of the technological infrastructure actually breaks, or from the ‘work’ side, e.g. when an infrastructure that always served its purpose breaks because an additional, maybe similar service is expected but can not be delivered. The same applies to ‘use innovations’ that can either occur that the technical infrastructure has been changed in such a way that it provides new opportunities or new requirements emerged from the current work activities, which can be met with the available technologies. It is important to note the subjectivity of our definitions: breakdowns may be only perceived, and an innovation as the local resolution of reverse salients represents a discovery of a usage which may already have been technologically available for some time. In the point of infrastructure, the relation between the activity spheres of technology design work and organizational practice becomes active.

We consider these the two 'defining moments' for the infrastructurer when he or she crosses the border from 'using' to 'reflecting/modifying' technology. In the timeline of a technological systems' existence, this is the 'point of infrastructure' when the routines of performing work meet the technology development activities of professional designers (see Fig. 1). From then on, the local development of infrastructure configuration and usage are considered as 'in situ'-design or design-in-use as opposed to the design-before-use (Pipek and Syrjänen 2006).

Distinguishing the targetedness of activities

In our perspective, we can identify layers of infrastructuring activities around that 'point of infrastructure'. First there is the in-situ design work of tailoring and configuring the infrastructure and appropriating and negotiating the actual work so that either the 'use innovation' becomes manifest in usage or that the obstruction caused by the breakdown can be eliminated. There is a stronger implicit tie between the activity spheres here, because the awareness around the now visible infrastructure results in a stonger sense of urgency with regard to infrastructure improvements. While these activities go on, the infrastructure remains visible, but it will sink again into the background of organizational practice eventually. But even before, there are relevant activities going on. We call those activities (of actors engaged in developing or considering the technological infrastructure that became visible in the 'point of infrastructure') 'preparatory design work'.

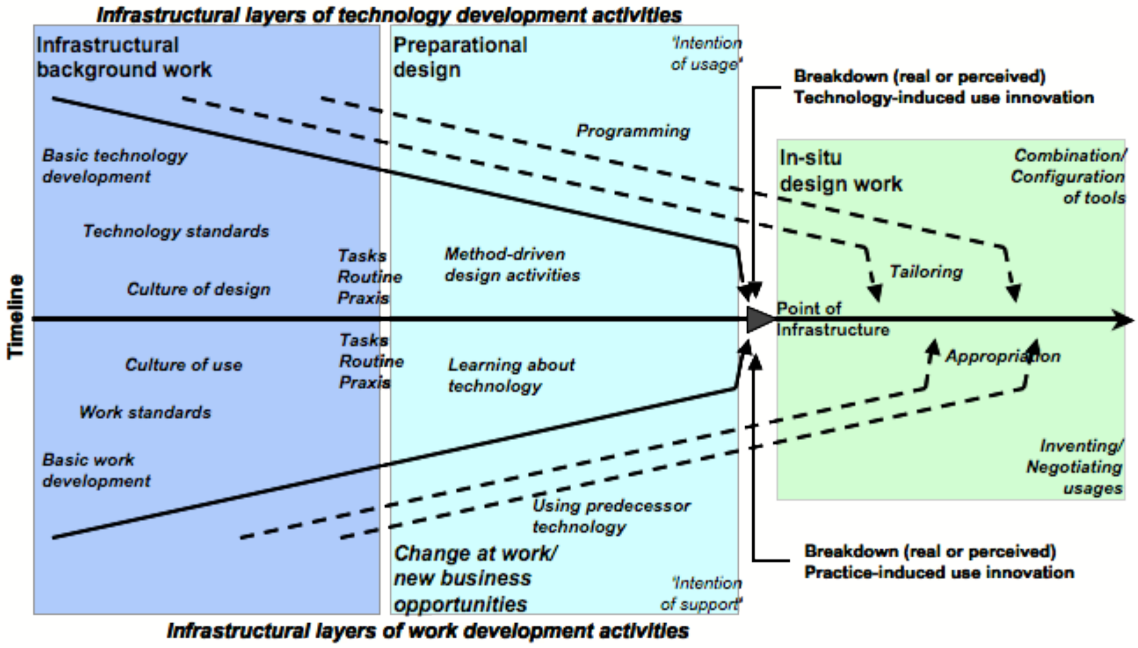

Fig. 1: Infrastructural layers of activities

With regard to technology development activities, those that indicate an 'intention of usage' (a concrete usage of the technology for the activities it is now considered for) belong to the category of preparatory design work. The 'work development activities' covers the activities that indicate an 'intention of support' (what technology may be able to support a certain work activity). As the infrastructure becomes visible in the point of infrastructure, so do the activities that contributed to that point of infrastructure. We call those activities, which have neither an 'intention of usage' nor an 'intention of support', 'infrastructural background work' (on the work activity side that is 'adaptive use of technology' as such. These activities have a more strategic nature that is informed by issues that may emerge from 'points of infrastructure' (e.g. the general need for more bandwidth).

We are aware of the fact that the borderline especially between 'preparatory design work' and 'infrastructural background work' is not very clearly defined. However, we believe that this terminology allows us to shed light on those activities relevant for successfully establishing the usage of an information system (either on the technology development side or on the work activity side) without a confirming the 'designer/user' dichotomy and the priorities it implies. Depending on the concrete case, it may be necessary to apply a broader view on 'infrastructuring' activities under consideration in the sense of including activities into the category of ‘preparatory design work’ that would be considered ‘infrastructural background work’ in other cases.

Resonance activities around points of infrastructure

While we developed our framework around a single point of infrastructure, it should be obvious that in a concrete work environment a number of ‘points of infrastructure’ may show maybe even on a weekly or daily basis. Each point of infrastructure does not only provoke in-situ design activities and makes visible prior preparatory activities, but it also creates resonance activities of observing and communicating aspects of what has become visible within the work environment or to other work environments. These resonance activities may become part of the infrastructural background work (e.g. when a breakdown illustrates the need for new strong encryption methods) or the preparatory work development or preparatory technology development of another point of infrastructure. Through resonance activities the social appropriation of certain technology usages can be captured, and the relations between different points of infrastructure become clear.

Towards methodological and tool support for Infrastructuring

With our framework, we are able to capture activities that are classically associated with ‘users’ as well as those that are classically associated with ‘designers’ in their relation with the point in time when they become relevant for the development of an IS infrastructure. It is the consideration of these activities where we can benefit from a ‘located accountabilities’ (Suchman 2002) perspective: Although the individual infrastructuring activities may be related to certain structures of professionalization or educational background, it is not the professional competence within these activities that is the main contribution to developing IT infrastructure. Rather, it is the engagement in ‘partial translations’ (Suchman 2002) between different professional worlds and different social and technological aspects that qualifies these activities.

We have identified five (six including the resonance activities) groups of activities in our framework that contribute to the successful establishment of technology usages. A methodological complex of ‘infrastructuring’ that would be equivalent to classical IS design methodologies needs to structure, moderate and support these activities in a way that it increases the fit between technology and organizational practice.

In our construction of the point of infrastructure and the activities that surround it we used backward thinking: Once we know a point of infrastructure we can recognize and distinguish the ‘design-before-use’ activities that contributed to it. But design-equivalent methodologies need to inform actors towards improved satisfaction in an unknown future. In our eyes, infrastructuring activities inform a search process for possible points of infrastructure that evoke an improvement of work infrastructures. Given the corrections that have to be applied during a process, the metaphor of a search process also applies to ordinary IS design methodologies, and in both cases it is important that a convergence can be achieved.

In our suggestions for the operationalization of our framework we try to inform this search process.

IS design methodologies mainly aim at two goals: Informing and structuring the designers’ work practice so that high-quality products can be delivered. While the designers’ self-organization (structuring of work) with regard to the actual production is to a certain extent only the designers’ business (these activities may be regarded as ‘preparational design’ with an ‘intention of usage’ which the designed product will support), the framework’s function of ‘informing’ is about the interaction between designer and user domains. From a methodological point it is concerned with the questions: when does the interaction take place? and: what is the kind and depth of information exchanged?

These questions are methodologically answered according to the interest of designers who define when they need information and what information they need. Our ‘Infrastructuring’ framework aims at adding a user-driven perspective to this,

- methodologically advising ‘users’ to perform frequent procedures aiming at infrastructure improvement that may *or may not* involve technological reconfigurations or the introduction of new tools,
- providing methods as well as tools to systematically perform these procedures and to

- prepare and engage in interactions with the traditional, professional designer sphere.

This may include 'meta-infrastructuring' activities, e.g. of users who aim at getting additional qualification (e.g. programming) in order to be more efficient in improving one's infrastructure.

We finally want to suggest a methodology that provides a variety of options for the shift in roles and collaborative relationships focusing on the improvement of a work infrastructure. It leads us beyond traditional approaches of developing products towards a long-term perspective on developing work infrastructures.

Operationalization for IS analysis and design

The framework aims at capturing, planning and supporting activities that contribute to the improvement of an IS infrastructure. Figure 1 provides a temporal structure that includes a notion of directedness of activities with regard to an intent to change and a notion of integrating contributions from the 'professional design' sphere as well as from the 'use' sphere, but we already clarified that from a methodological perspective we can only try to support the search process that leads to the emergence of points of infrastructure that lead to an improvement of work infrastructures. We now discuss how to identify activities as contributing to an improvement of infrastructure while they go on, not only post-mortem. For the operationalization of our framework, we draw again on the infrastructure characteristics worked out by Star and Bowker (2002) and look at activities that change:

- the embeddedness of infrastructures in other social and technological structures: activities that relate to connecting different technological and social structures, activities that change standards, routines or traditions that mediate between different technological and social structures;
- the transparency in invisibly supported tasks: activities that change the visibility of (and thus also the awareness for) an infrastructure;
- both the spatial and temporal reach or scope: activities that change the longevity of an infrastructure, or that add new elements or application areas to it,

- the taken-for-grantedness of artifacts and organizational arrangements learned as part of membership: activities that change formal and informal types of membership;
- infrastructures shape and are shaped by the conventions of practice: activities that aim at changing conventions of practice; activities that aim at imposing existing practice on new technologies;
- infrastructures are plugged into other infrastructures and tools in a standardized fashion, though they are also modified by scope and conflicting (local) conventions: activities that change standards that mediate between infrastructures (may also include activities that aim at local specializations of standards); activities that change the scope to which standards apply; activities that articulate or mediate conflicts;
- infrastructures do not grow de novo, they wrestle with the inertia of the installed based and inherit strengths and limitations from that base: activities which interface and align new applications with existing IT infrastructures; activities which challenge and develop existing practices;
- the normally invisible infrastructures become visible upon breakdown: activities that help articulating a breakdown; recovery activities after a breakdown.

We now will describe an illustrating case study and identify infrastructuring activities that would not be covered or supported by traditional IS design methodologies.

Infrastructuring: An empirical case study

We illustrate our framework by presenting a long-term study about the introduction, appropriation, and removal of a groupware infrastructure in a German state government. We first describe the course of the case itself and describe relevant activities that contributed to the shaping (as we will see, ‘improving’ is subject to quite different interpretations of the actors involved) of the new infrastructure. We will then sort these activities with regard to the different phases of our model and their impact on the work infrastructure.

Setting and case description

The case study reported here took place in the government of a Northern German state. The case is extensively covered in Pipek and Wulf (1999) and Pipek and Wulf (2006). In this contribution we focus on work processes connecting the state government located in the state's capital with the Bundesrat. The Bundesrat is the second chamber of the German parliament representing the 16 states. It is located in the federal capital, at that time in Bonn. The State Chancellery (SC) plays an important role within the state government. It channels information from and to the different state ministries. Within the State Chancellery one organizational unit (a head and three employees) is responsible for the coordination of the different state ministries within the process of political decision making. The State Representative Body (SRB) is located in the federal capital. In the SRB about 30 people are occupied with representing the interests of their state in the process of federal legislation. The SRB belongs to the State Chancellery. The SRB is responsible for transferring documents and distributing information between the state government and the Bundesrat. A detailed description of related work processes will be given later.

Before the beginning of the project, the IT infrastructure consisted of only some PCs connected via a network, with the usual Microsoft Office™ software installed. They were mainly used by typists and secretaries. The SRB had no IT-department of its own, because the IT-department associated with the SRB belonged to the State Chancellery in the state's capital, 700 kilometers away. When problems occurred, they asked for IT-support from another state's Representative Body in the same building.

The software development process was based on an off-the-shelf groupware application: LINKWORKS™ by Digital. It was introduced in the government administration of the state and its SRB in the federal capital. The features of the system offered shared workspaces, electronic circulation folders, e-mail (including electronic document transport), and basic notification services.[2] Starting from LINKWORKS, the research institutes and the industrial partner participating in the research effort developed new system versions evolutionarily according to the specific requirements of the users. During the course of the research, a variety of qualitative methods were used for requirements elicitation and analytical purposes (Pipek and Wulf 2006). The contact between researchers and the application field remained intense over almost four years with at least bi-weekly meetings.

Preparing a session of the Bundesrat

We will now describe the main work processes of the SRB in the federal capital as they were given in the beginning of the project. Aside from the core activity described here, other activities, for example the organization of events or the writing of press releases also involved groupware usage (e.g. collaborative text writing) at a later stage of the project. However, these activities will not be discussed here.

The main task of a SRB is the management of the information flow between the federal and the state capital concerning the legislation procedure in the Bundesrat. The Bundesrat meets every three weeks to discuss and vote on an agenda of about 80 different issues. The SRB and specific sections of the State Chancellery and the state ministries cooperate in determining the state's vote on each of those issues. In preparing a session of the Bundesrat, we distinguish four different, but closely connected work processes.

The first work process is referred to as “Issue Distribution”, which deals with the distribution of information material from the Bundesrat to the appropriate sections of the state government. Information usually circulated as printed information, which involved internal as well as external courier services.

The second work process prepares the negotiation processes which leads to the state's vote. We call this one “Vote Preparation” (cf. Figure 2). Two weeks before the meeting of the

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2 This describes the state in the beginning of 1994, where neither the web nor Internet-based mail were as widely used as they are today.

Bundesrat its different commissions (e.g. commission for internal affairs) meet to discuss and vote on the different issues of the next agenda. An issue is typically handled in several commissions. The state is represented in each commission by one employee of the SRB who typically is the head of the corresponding section in the SRB. After the meetings of the commissions a personal protocol including main discussion points and results of test voting is hand-written by each section head and passed to a secretary for typing, followed by further correcting and re-typing until the result is satisfactory. Then it is sent by fax to the corresponding state ministry. At the same time, a secretary of the Bundesrat writes an official protocol about each of the commissions' meetings and sends the paper document via the SRB to the corresponding state ministries. Within the commissions each state ministry acts independently by means of the corresponding section of the SRB. To coordinate the different ministries' activities concerning one issue of the agenda, the SRB invented a coordination mechanism based on a form sheet.

For every issue, one section of the SRB takes main responsibility (issue leader-ship). The issue leader creates a hand-written form sheet for each issue for which he is responsible. He marks the issue and gives a rough political judgment. He adds the result of the test voting in the commission of the Bundesrat, for which he is responsible. Finally he states the names of other sections of the SRB, whose commissions also deal with that issue. On the form sheet he leaves space for the other sections to add their comments and their commission's test vote. This form sheet is typed and printed by a secretary, and re-checked by the issue leader who then carries it to the heads of the other sections involved in order to get the result of their test votes. To reach the heads of each section, this process may require several attempts, being that the section heads are absent quite often. Finally, all form sheets are given to one section head who is responsible for collecting and sending them by fax to the section of the State Chancellery which is responsible for the coordination of the state's activities in the Bundesrat. The deadline for the arrival of the papers is always on the Tuesday before the meeting of the Bundesrat, which typically leads to high time pressure in completing the papers. The Chancellery uses the form sheets to get a survey on the state of political process and to recognize inconsistent activities of different ministries.

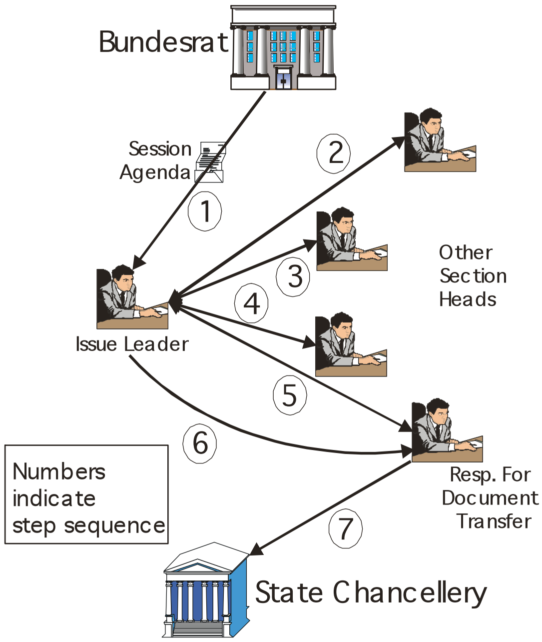

Fig. 2: “Vote Preparation” in the SRB

The third work process (Vote Negotiation) mainly takes place in the State Chancellery. The state's vote is now negotiated at the government level. Having identified possible conflicts between different ministries, the employees of the State Chancellery contact the conflicting ministries, identify the political dissenter and try to find a compromise. In the State Chancellery the negotiation results are summarized for the state cabinet which finally decides how to act on each issue in a meeting three days before the session of the Bundesrat (agree, disagree, abstain, or suggest a modification of the given issue proposal). The results are then transmitted via fax to the SRB where they are used to prepare the Bundesrat session (negotiation with other states, additional test votes, etc.).

The forth process is the so called “Session Preparation”. The day before the meeting of the Bundesrat the modified proposals from the other states are sent to the State Chancellery and ministries.

The development of a work infrastructure

To give an overview of the development of the groupware infrastructure, we roughly distinguish the four phases introduction, use, removal, and re-introduction of the Groupware. The introduction phase covered the analysis of the work processes and the identification of processes that should be improved with the help of the new tools. It also deals with the installation of the groupware and related qualification processes. During the use phase, the gradual appropriation of the new technological infrastructure took place by the organization. Technological fine-tuning, adjustments to new external developments, discovering, and implementing organizational innovations, and qualification measures for new users were activities during this phase. The removal phase began with the decision to remove the groupware infrastructure, which took about three months. It covered activities such as saving data and realigning work process. During the re-introduction phase a new groupware was provided. This phase was similar to the introduction phase, although was stronger influenced by given expectations and experiences. Data had to be reintegrated and work processes needed to be aligned to the new system.

The introduction of Groupware into the SRB started quite early about three months after the project started. It could - for the SRB - be considered as completed about 15 months later. The subsequent usage phase ended about three and a half years later, when the decision for the removal had been made. The groupware application was de-installed within three months, by December 1998. In 1999, after the research project had ended, another groupware product was introduced.

We now describe several cases of 'infrastructuring' activities that illustrate our framework.

Cases of 'Infrastructuring'

In the following, we describe some cases of infrastructuring activities that would not be acknowledged in their full creative potential in traditional IS development methodologies. We describe them using the concepts from our framework. Since the goal of our framework would be to advise for methods to support these activities, we also give some examples of methods that we could derive from the examples described and that would in our eyes provide a more comprehensive support for successfully establishing IT infrastructure usages in an organizational practice.

Case 1: Using a groupware infrastructure

Our first example of a 'point of infrastructure' is the use of a groupware infrastructure as such, after installing the first network computers outside the typing pool of the SRB. The efforts of the project team regarding requirements elicitation and groupware configuration (which also included the development of smaller applications to integrate the groupware and the office software) represent the traditional designer approach towards installing such an information system. They represent activities that had clear 'intentions of usage' (using groupware for document exchange, using groupware for process/workflow management) and were based on a web of 'infrastructural background activities, e.g. around the development of low-level communication protocols. But there were more activities worth considering in the application domain. The development of a division of labor in document production (dictating and typing) and an associated infrastructure (recording machines, computers with a text processing software, internal courier service) laid a foundation to make the usage of the groupware immediately beneficial (by dramatically increasing the speed of document exchange through sending electronic documents). Activities which tried to establish the participation of the SRB in the research project (that could also be interpreted as becoming 'members of group of groupware practitioners') also carried with them an 'intention of support', and required a general reflection of the stakeholders about interesting technological developments. Activities of negotiating which staff members participate first, and how the data exchange between the sections and the typing pool will be organized (developing 'conventions of practice'), can be considered 'in-situ design'.

For the occurrence of this 'point of infrastructure' two explanation patterns could be used. We could describe it as a result of an 'infrastructure breakdown' since the typing pool had become an extreme bottleneck for the session preparation activities of the section heads. But of course a description of the event as a ‘technology-induced use innovation’ would also be possible.

Deriving recommendations for ‘infrastructuring’ measures and support from this case, we could suggest to frequently ask interested users to reflect on interesting technological developments, and to actively familiarize with technologies colleagues use already, but also to give room for negotiating the usage of a new technology even after it is being introduced.

Case 2: Innovating the ‘Vote Preparation’ Process

The ‘Vote Preparation’ process was improved through faster document exchange and less document exchange (the section heads performed minor text corrections themselves), but the main improvement came with the parallelization of the sequential process part of filling in the form. Neither the project members, who were involved in the requirements elicitation, nor the users themselves, after being informed about the features of the application, recognized this potential for process innovation immediately. During a site visit several months after the introduction, a project member and a section head discussed rather accidentally a stack of "form sheets" (see description of the Vote Preparation process) on the section head's desk. As a result of their discussion they came up with the idea that the process of filling out the "form sheets" could be supported by the object-sharing feature of the groupware. They involved other section heads to discuss their idea and work out an electronically supported procedure.

In the newly developed usage, a document template representing by the form sheet was stored in a public folder. The issue leader could copy it from there and fill it out for the specific issues for which he is responsible. He could enter his commission's test voting results and further comments. A link to the document was then sent via e-mail to all the other section heads being involved in that issue. The recipients can enter the vote of their section whenever they like. Because of using a shared document, it is not necessary to maintain a temporal order. After all sections contributing to an issue have entered their votes and comments, the issue leader sends a link to the completed form sheet via e-mail to the section head responsible for transferring the documents to the State Chancellery. So the "shared workspace"-feature of the LinkWorks system allows to overcome the sequential order to fill in votes, which was immanent in the paper based version of the Vote Preparation process. Nevertheless, additional conventions were needed to avoid a rush of document accesses when the deadline approaches.

In this example, it is significant that the new infrastructure usage (we could also classify as 'technology-induced use innovation') was a shared development effort of a 'software expert' and a 'practice expert'. The realization of the idea did require some technological skill but also a very sound knowledge of the framing conditions of the process (e.g. the increasing time pressure preceding the submission of the vote). With the development of this usage, the groupware became an inevitable part of the organizations core practices.

The establishment of frequent meetings (inducing new 'group memberships') of design experts and practice expert was an important infrastructuring activity preceding this usage development. The practice of using a form for collecting the test votes also prepared the use of a shared document.

On a methodological level, we could suggest infrastructuring measures like establishing use reflection groups with mixed expertise or stimulating frequent considerations of coordination mechanisms like the form sheet as facilitators for the development of new infrastructure usages.

Case 3: Discovering individual infrastructure usages

The examples we gave so far already showed different degrees of 'localness' of infrastructure usages. We were also able to observe 'most local' or individual usage inventions.

During the introduction of the groupware infrastructure, many section heads were equipped with computers for the first time. The intention was to connect them to the groupware infrastructure, but there was no indication that the section heads were eager to engage in other computer usages, especially text production. After the introduction of the groupware more and more section heads found it convenient to be able to do minor text modifications by themselves, avoiding to wait for the typists. Although it was the individual decision (technology-induced use innovation) of every section head to stronger engage in text production, the effect summed up to a reduction of the positions of typists from four to just one half position within a period of three years. The new practice of text production spread through the demonstration and observation of technology usages. It is an example for (non-design) infrastructuring activities that manifest 'learning as part of membership'. In our framework these are also examples for resonance activities.

A similar case is the development of one of the user into a local system administrator. Based on the necessities of everyday practice, one staff member with a strong interest in information technology slowly familiarized himself with the configuration interface of the groupware with some help of the project team members that provided IT support. During the course of the project, groupware administration became officially acknowledged as a part of his job description. This is an example of technology-centred learning as an important infrastructuring activity.

A third example for a (very) individual infrastructure usage is provided by the story of the remaining typist. Being confronted with a dramatic decrease of actors needing her expertise, she became afraid to lose her job. Although it was the official policy to share document templates necessary for the organization of work, she decided to store several template in her personal workspace and to only give them out upon request. That way she hoped to secure her job and caused minor 'infrastructure breakdowns' when she was on vacation.

The latter cases may serve as examples of practice-induced use innovations, since a practice that developed gave the major stimulus for their development. From an 'infrastructuring'-oriented design perspective, we would suggest measures that do not only target the exchange of infrastructure usages, but also stimulate the assessment of the values the stakeholders involved in using the infrastructure.

Case 4: Continued usage patterns

A striking and presumably very unique experience in our case study was the observation of the complete removal of a software infrastructure. During the course of the research project, project members did not only engage in observation of the developing infrastructure, but also provided support to keep the infrastructure running and to technologically implement use innovations. With the end of the project coming closer, the IT department of the SRB (being located in the SC, about 700 miles away) was not able to provide support for the maintenance of the groupware infrastructure. As a consequence, the groupware and the network infrastructure it used were removed.

One interesting problem in this situation was that the groupware product was not prepared for being removed. A fallback to a 'lower' infrastructural level (here: the operating system) could only be performed by additional programming efforts to efficiently remove all files from the groupware database and store them at the operating system level.

Even more interesting were the changes the 'Voting preparation' process underwent. The removal of the groupware constituted an 'infrastructure breakdown' par excellence. However, the process structure, especially the parallelization pattern developed in another use innovation (see case 2), sustained. The old, paper-based routine was not revived. Users started to use floppy disks with the voting form sheet instead of the document link that was sent by email in case 2. After the re-introduction of a second groupware product, the same use pattern was implemented again, using a shared workspace.

This example impressively demonstrates that the strength of use patterns coined by practice and conventions may equal the strength of use patterns technologically enforced within infrastructures. In our eyes this shows that applying an infrastructure perspective to the development and establishment of information systems needs an integral consideration of technological and social/organizational aspects.

We would suggest infrastructuring activities based on these experiences, which involve the frequent reflection on strategies for an 'infrastructure fallback' (returning to a lower and presumably more reliable infrastructural level in the case of an infrastructure breakdown) and means to express and collect usage documentations which would assist the re-establishment of usages based on new, but similar, technological infrastructures.

Additional comment: Failed anticipated usages

We learnt in this case study that the successful establishment of a groupware as an enhancement of a work infrastructure cannot be fully credited to the efforts associated with classical IS design methodologies. There are a lot of important activities that are marginalized by a traditional designer-centric perspective and are not acknowledged with their full creative potential by the 'adoption' perspective.

A further indicator for the necessity of a comprehensive perspective on developing work infrastructures are usages which were intended by the designers but never manifested in actual infrastructure use practice. One example is the workflow management functionality in LinkWorks, that was considered 'very important' in the initial requirements elicitation phase of the groupware system. It was never actually used, although the core processes of the SRB (see descriptions above) were easily describable in a formal language. However, it turned out that the rhythm enforced by the Bundesrat sessions had been so firmly integrated in the everyday practices of the SRB that an additional technological support would not have created benefit worth the cost of modeling.

A second example was the group calendar functionality of the groupware product introduced after the removal of the first groupware infrastructure. Although being one of the main selling points of the product and being high on the agenda of the introductory workshop of the groupware, it never materialized in actual use practices. The efforts to train for the second groupware infrastructure were only a fraction of the efforts invested during the first introduction phase because the management decided to rely on the use experiences gathered before. However, they did not cover the use of a group calendar.

This finding stresses the necessity for bridging the gap between technology design and appropriation. With the 'infrastructuring' framework, we were able to capture these activities.

Further aspects of 'Infrastructuring' in practice

We developed a perspective that regards information systems as 'work infrastructures' which allows us to apply conceptualizations from the research on E-Infrastructures on the design and adoption of information systems. Our ultimate goal is to inform actors in the process of developing an organization's infrastructure with methods which acknowledge all necessary contributions of the various actors involved. While it will take more case studies to refine our approach, we can draw on earlier research on 'affordances' and 'appropriation support' further discuss ideas for the support of infrastructuring activities.

The 'design of everyday infrastructures'

One focal point of our concept was the 'point of infrastructure', where the activities of professional design and continuous re-conceptualizations of possible uses in the application domain result in activities to discover or develop new infrastructure usages which may or may not involve technological changes. This 'point of infrastructure' is always local, and the accessibility of an infrastructure for usage detection or for usage development is significantly influenced by the way it is presented to possible users. In his popular book 'The Design of Everyday Things', Norman (2001) surprisingly (or maybe not) uses a lot of design examples that show 'user interfaces' of infrastructures, e.g. water faucets, light switches, door handles, and button controls on various electronic devices, to illustrate rules for good design. He also discusses visibility and standardization as design aspects, naturally from a slightly different angle than it has been done in the discussion of E-Infrastructures. Visibility relates to 'traceability' of the inner workings of an infrastructure in case it is necessary for its correct use.. Standardization also relates to an artifact's use (by means of standardization of the user interface) in case an infrastructure can not be cloaked into existing use traditions.

However, Norman's (2001) discussion reveals an important difference between information systems seen as infrastructures and 'classic' infrastructures. The handles which he describes remain simple, no matter how complicated the use situation gets. The 'interfaces' presented offer support and affordances for use situations, they do not provide support in breakdown situations, and they do not in themselves provide means to stimulate use innovations. The partly virtual nature of software infrastructures makes it possible to provide simple interfaces for use, but also additional, more complex interfaces to support infrastructuring activities. This nature also allows a development of information infrastructures in much smaller and maybe also more local and more divergent steps, consolidated by negotiations for standardization that are necessary to establish a shared use. These negotiations would also be part of the infrastructuring activities we consider. We now give some examples for technical support of infrastructuring activities from our research.

Beyond theorizing: Technological support for 'infrastructuring

In earlier work, we developed (software) 'appropriation' from an analytical concept of describing phenomena of technology in use to a concept that covers activities users perform in order to make sense of technology. The activity-centric interpretation of appropriation allowed us to identify and classify possible support infrastructures for 'appropriation activities' (Pipek 2005):

- Basic technological support: Building highly flexible systems,
- Articulation support: Support for technology-related articulations (real and online),
- Historicity support: Visualize appropriation as a process of emerging technologies and usages, e.g. by documenting earlier configuration decisions, providing retrievable storage of configuration and usage descriptions,
- Decision support: If an agreement is required in a collaborative appropriation activity, voting and polling needs to be provided,
- Demonstration support: Support showing usages from one user (group) to another user (group), provide necessary channels of communication,
- Observation support: Support the visualization of (accumulated) information concerning the use of tools and functions in an organizational context.
- Simulation support: Show effects of possible usage in an exemplified or actual organizational setting (makes only sense if the necessary computational basis can be established),

- Exploration support: Combination of simulation with extended support for technology configurations and test bed manipulations, individual vs. collaborative exploration modes,
- Explanation support: Explains reasons for application behavior, fully automated support vs. user-user- or user-expert-communication.
- Delegation support: Support delegation patterns within configuration activities; provide remote configuration facilities.
- (Re-) Design support: feedback to designers on the appropriation processes

In our Infrastructuring framework, these support options could be beneficial for preparatory work development activities and in-situ design activities. Technological support for preparatory technology development activities is one of the classical domains within software engineering (Integrated Development Environments like IBM's 'Eclipse' platform). The support options also strongly support resonance activities within the work development sphere of activities. Re-Design support also describes a very specific infrastructure for resonance activities as it creates a permanent bridge between the technology development side and the work development side around a specific entity of infrastructure the support functionality is embedded in.

All the supported activities are not covered by traditional IS design methodologies. We will provide some examples of technical support for 'infrastructuring' which all relate to the idea of embedding platforms for user communities and user collaboration within the infrastructures and to prepare representations of software infrastructures that allow to easily articulate issues regarding current practice and possible modifications to the infrastructure.

Use Discourse Environments

We developed the concept of 'use discourse environments' to support users in negotiating the configuration of the software infrastructures they use. The main idea was to:

- provide users with a communication platform that is embedded in the infrastructure they use, (e.g. a discussion forum),

- provide means to easily articulate and visualize issues around using and configuring the infrastructure, (e.g. by providing representations of the software used and support for annotated screenshots),
- provide means to organize these communication and negotiation processes (e.g. by providing voting support and process visualizations).

Use discourse environments support preparational work development activities, in-situ design activities and build a platform for resonance activities. The concept was implemented in two prototypes and evaluated in real organizations (Pipek 2005). The support for articulation, demonstration, negotiation and exploration activities was well accepted, and partially resulted in use discourses that went beyond the software infrastructures the concept was embedded in. In our framework, we would classify these activities as infrastructuring with a 'preparational' or an 'in-use design' character altering the infrastructure characteristics that relate to 'conventions of practice' and 'membership'.

ChiC – Community Help in Context

Stevens and Wiedenhöfer (2006) presented a concept to provide a similar support for the case of an infrastructure breakdown. Based on the assumption that pressing the 'F1'-Key during the use of a software application indicates a situation in which the work infrastructure does not deliver the service the user expects, they provided a wiki-based 'help system' where users can modify and extend help descriptions provided by the software manufacturer. Thus, making it possible to specialize the help descriptions to the needs of local usages. Together with a guiding context model, this idea delivered articulation, demonstration, exploration, and explanation support. This functionality can support in-situ design activities, preparational work development activities and resonance activities, but also preparational technology development activities if technology developers get access to the (possibly confidential) information.

Infrastructure Probes

Based on the concept of 'Cultural Probes' (Gaver et al. 1999), we developed the concept of 'infrastructure probes' (Dörner et al. 2008). A toolkit for self-documentation of infrastructure usages allows recording the 'virtual' tools at the workplace (by means of a software snapshot tool and an infrastructure-embedded wiki to document actual or envisioned infrastructure usages) as well as documenting 'real' parts of the work infrastructure such as spatial arrangements or constraints that shape local infrastructure usages (by means of a digital camera and stickers to 'annotate' the work environments). So, it will be possible to support infrastructuring activities where 'telling' about breakdowns or use innovations have a 'real' dimension. This tool can be a valuable mediator between IT-based and non-IT-based aspects of a work infrastructure. It obviously supports resonance activities, but also preparatory work development activities and in-situ design activities.

While these approaches aim at supporting infrastructuring activities on the 'user' side, they can easily be extended to integrate other actors like professional designers.

Conclusion

Traditionally, design methods in IS have a focus on developing individual products, accompanied with measures to embed them into existing technological and social environments where these products will be 'adopted'. These methodologies focus on the development of technology while missing many activities and decisions that need to be performed in the application domains.

The research on E-Infrastructures provides interesting concepts to overcome the traditional distinction between IT design and IT adoption. In a perspective that focuses on the improvement of an organization's infrastructure, not of specific individual products, lies potential to integrate the multiple social and technological layers. Such a perspective allows to acknowledge the contributions from designers of information technology as well as from innovators of technology-enhanced practices. We identified Star and Ruhleder's eight characteristics of infrastructure as an important conceptualization that allows to capture infrastructure development not only as an occurring socio-technical phenomenon, but as a set of activities of technology designers and 'users' that only in their entirety guarantee the successful establishment of information system usages.

In our account of technology development methodologies we described deficiencies that have to do with 'infrastructural aspects' of modern information systems. Their complexity, their dependency on standardized interfaces between the interior and the exterior of a design process and their invisibility in use complicate design approaches that focus on the self-organization of professional designers.

For organizational settings, we cannot understand or improve infrastructures without integrating creative activities of the 'ordinary' user. Inspired by Star and Bowker's article 'How to Infrastructure' we followed the impulse to look at the activities that make infrastructure improvements happen in order to derive methodological and tool support for them. 'Infrastructuring', understood as re-conceptualizing the own work in the context of existing, potential or envisioned IT tools is a natural part of every user's activities. Large parts of these activities are not delegable to some 'management' level or the next professional design process. Consequently, activities of infrastructuring should be addressed in IS design frameworks to capture the complete chain of innovations that help establishing successful technology usages.

We chose the description of the characteristics of infrastructure by Star and Ruhleder (1996) as a starting point to develop a framework for capturing 'infrastructuring' activities of the many actors involved in developing a work infrastructure also because it nicely links technological and social aspects of infrastructures. We especially used the notions of the 'taken-for-grantedness of infrastructure' and of the 'invisible work support, but visible upon breakdown' to develop the notion of information systems as 'work infrastructures', and to describe a framework for 'Infrastructuring' that revolves around the 'point of infrastructure' when the usage of a technological infrastructure becomes manifest locally. Starting from that point, we can describe past activities of 'Infrastructuring' which contributed to the development of the given usage as well as possible future activities to establish or modify that usage. Acknowledging the contributions of these activities to a successful development of IT infrastructures, we described parts of an 'Infrastructuring' methodology which addresses professional IT designers as well as all other actors involved. We identified five groups of activities that should be informed and supported by methodological approaches as well as Infratsructuring tools. The support cannot be as deterministi as in classical IS deisgn approaches, we see it rather as informing a search process for a 'point of infrastructure' that helps improving the work infrastructure. To illustrate its usefulness, we revisited an earlier case that is rather unique because it presented a long-term study (more than four years of observation and intervention with regard to a groupware infrastructure in a German state government) and it involved 'infrastructurers' from the organizational side as well as technology developers.

The necessity for a broader perspective on design has been acknowledged in other fields of product development, as well (von Hippel and Katz, 2002; von Hippel, 2005). However, in the domain of information technology our perspective offers a unique opportunity. Software as the most important fabric of information infrastructures is versatile to an extend that it can support the actual use as well as activities which bridge between design and use. The semi-material nature of software makes it less dependent on physical and spatial constraints. It allows building a rich variety of user interfaces which in turn allow different, more flexible divisions of labor. So software offers an interesting opportunity to overcome the traditional dichotomy between 'professional designers' and 'users'.

Information and software are quite unique infrastructural materials. Their versatility to support their use as an infrastructure as well as almost all meta-activities of infrastructuring results in new approaches to integrate use, maintenance, and design. In our eyes, it is a crucial task for IS as a scientific discipline to capture and exploit these infrastructural opportunities. The concept of infrastructure may also become an important boundary object to overcome the gap between the analytical and the design-oriented schools of thinking within the IS community as addressed by Hevner et al. (2004).

In addition to these considerations, information systems are an interesting case to provide new questions and challenges to the field of Science and Technology Studies (where the foundations for our ideas have been developed), as they have – contrary to other types of infrastructure – the reflexive characteristics: If we consider 'Information' as the material they are able to process and distribute, it becomes obvious that with an information transfer we can also provide meta-information about the information transfer in the very same infrastructure. Even parts of the infrastructure (e.g. software downloads or updates) can be operated on the same level as other types of information. What offers interesting potential for 'Infrastructuring' support, could also be an interesting focus for discussing information systems against earlier infrastructures and to re-analyze the relation between infrastructural and societal change (Van der Vleuten 2004).

Acknowledgements

We would like to thank the anonymous reviewers as well as the colleagues who contributed to this research valuable discussions, especially Helena Karasti, Gunnar Stevens, Anna-Liisa Syrjänen, and Torben Wiedenhöfer. This research was supported by the German National Science Fondations under its grants 'Kontextadaptive Interaktion in Cooperative Knowledge Work (CONTici)' and the research centre 'Media Upheavals' (DFG FK 615).

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