RE-CONCEPTUALIZING DESIGN OF INFRASTRUCTURES: STABILIZING AND INNOVATING THROUGH MAINTENANCE WORK

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Abstract:

Recent research in IS has demonstrated the challenges in developing and establishing large-scale digital infrastructures across various settings. Traditionally this literature has contrasted a top-down approach with an evolutionary approach – often conceptualized as 'installed base cultivation'. This paper investigates the role of maintenance and repair work that as essential design activities for digital infrastructure evolution. Empirically, the paper reports from a longitudinal case study of an international company, and especially observe how maintenance work is pivotal for building competence for extending the installed base and for reducing technical debt of large-scale digital infrastructures. The paper contributes to the body of literature on digital infrastructures by analytically and empirically illustrating how maintenance and repair work comprise an essential mechanism for producing both stability and innovation.

Keywords: Infrastructuring, Maintenance Work, Digital Platforms, Case Study

1. Introduction

Recently, the IS and CSCW literatures have been expanded with multidisciplinary studies on information infrastructures empirically displaying and theorizing how large-scale collaborative systems evolve and are used across communities and contexts. An important contribution of this body of work has been to emphasize that infrastructures are different from traditional systems and seldom designed from scratch, but rather evolve or grow over longer periods of (infrastructure) time (Edwards et al., 2007; Hanseth and Lundberg, 2001; Karasti et al., 2010; Monteiro et al. 2013; Pollock and Williams, 2010; Ribes and Lee, 2010). Recognizing that an infrastructure is always changing, the concept of 'infrastructuring' has been coined in order to analytically emphasise its performative and evolving characteristics involving both users and designers (Bossen and Markussen, 2010; Parmiggiani et al., 2015; Pipek and Wulf, 2009).

Extending upon these insights and the concept of infrastructuring, in this paper we turn our attention to the different categories of *work* and *actors* involved in infrastructuring collaboration in contemporary organizations. First, drawing on recent studies of maintenance and repair work (Ahmed et al., 2015; Jackson, 2014; Jackson et al. 2012), there is a need for focusing on the role and nature of maintenance and repair work in infrastructuring collaboration. Arguably, this work is especially relevant in relation to infrastructuring as this involve dealing with incompatible technologies, multiple sites and local practices (Ellingsen and Monteiro, 2006; Monteiro et al., 2013). Thus, we anticipate that maintenance and repair work are not only conducted on occasions when infrastructure breaks down, but that maintenance work is continuous and highly intertwined with design and use of collaborative technologies. Second, a focus on maintenance and repair work as an integral part of infrastructuring collaboration also brings front-stage multiple actors organizing and conducting this work as well as a wider ecosystem of digital platform technologies involved. Hence, maintenance and repair work are not merely conducted on-site close to users and organizational actors, but may be outsourced or conducted at multiple sites by multiple actors making up a boarder digital ecosystem

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(Pollock and Williams, 2012). Moreover, we presume that maintenance and repair work is inherent in enacting generic platforms in organizations.

Taking this together, in this paper we attempt to answer the following research question: *What are the characteristics and role of maintenance and repair work in infrastructuring digital platforms for collaboration in organizations?*

In investigating this research question, we draw from a longitudinal case study of an oilfield service company, referred to as GlobalOil, that mainly design and build advanced drilling equipment and tools that are installed and operated on oilrigs all over the world. GlobalOil has over the last ten years been subject to several acquisitions and mergers expanding their services and products globally. Accompanying these changes, the development of an information infrastructure supporting standardization of document management and collaboration within and across sites, as well as across different communities of engineers, was initiated. In our research we have especially followed a main component of this infrastructure, a generic software platform known as Microsoft SharePoint typically used for document management and collaboration. We followed the infrastructuring of this generic platform over three main versions (2007, 2010, 2013) covering seven years, especially focusing on the various maintenance and repair work involved in sustaining and innovating this infrastructure over time.

Based on this, we contribute by theorizing the role of maintenance and repair work as a mechanism for infrastructuring collaboration. More accurately, we illustrate how maintenance and repair work perform important ‘boundary work’ (Bowker and Star, 2000; Carlile, 2004; Levina and Vaast, 2005) in connecting and re-connecting parts of infrastructure and to translate across different communities. Furthermore, we also suggest that maintenance and repair work are essential in experimenting and learning about new features and versions of generic platforms, and thus conceptualize this as a ‘learning-by-trying’ process (Fleck, 1994). In this way, maintenance and repair work draw from a multifaceted and heterogeneous body of knowledge about different communities of practice, installed base of existing infrastructure, and new generic platform features. Henceforth, we question traditional perceptions about maintenance as non-strategic, straight-forward, and easily outsourced. In contrast, and similar to Jackson (2014), we see that a significant amount maintenance and repair work as essential in infrastructuring collaboration and thus as a source for continuous innovation. These findings have important implications for infrastructuring for collaboration and also for the focus and understanding of ‘design’ in the context of infrastructures. The paper further discusses these issues as well as some directions for future research.

This paper is structured as follows. In the next section, relevant literature on design of information infrastructure is presented. We also outline our focus on how design, use, maintenance and repair work are intertwined in infrastructuring processes, and the theoretical lens of infrastructuring. Next, in section 3, the research context of GlobalOil and case study method is presented. Then, in section 4, the case story is presented through two vignettes of the infrastructuring process in GlobalOil. In section 5, we characterise and conceptualize the nature of maintenance and repair work in infrastructuring digital platforms for collaboration. Moreover, in section 6, we discuss the implications of our conceptualization of maintenance and repair work in infrastructuring processes in general, and for digital platforms in particular. In the last section, we conclude this essay by pointing at the limitations of this research and potential themes for future research in IS and CSCW.

2. Background on infrastructuring and maintenance work

Infrastructure studies in both IS and CSCW, shows how design of information infrastructures in both organizationally and technically ways are relatively more complex than design of traditional technologies and systems (Bossen and Markussen, 2010; Bygstad, 2010; Ellingsen and Monteiro, 2002; Monteiro et al., 2013; Tilson et al., 2010). However, from an infrastructure perspective, there has been a reluctance to use the term ‘design’ as it has a strong connotation towards designing from ‘scratch’, privileging of technical design, and having a short-term bias. Such a perspective would imply that designers have the capability to design infrastructures the way they want to irrespective of existing infrastructures and practices. In contrast, there is a widespread insight from recent infrastructure literature that infrastructures are *not designed* in a traditional sense as they are rather built on, or in relation to, an *installed base* (Grisot et al., 2014; Hanseth and Lyytinen, 2010; Star and Ruhleder, 1996; Aanestad and Jensen, 2011). An installed base in this context refers to a core set of existing heterogeneous and interconnected arrangements of information systems, practices and other artifacts that are used in a collaborative environment. Any 'new' information infrastructure will thus have to relate to this existing installed base. Failing to do so, would likely imply the failure of any new infrastructure. Hepsø et al. (2009) illustrate this point when reporting from a study of development of a corporate-wide collaboration infrastructure for various communities of engineers at a multinational oil and gas company. The study shows how different communities of engineers use specialized information systems and have multiple local work practices for storing and structuring information about oil wells, and that this comprises a powerful installed-base when attempting to replace this plurality with one common infrastructure for sharing and collaborating. Hence, when it comes to information infrastructures, design is inherently connected to a heterogeneous installed base of existing systems, artifacts and practices.

The importance of an installed base is also reflected in Hanseth and Lyytinen (2010) who develop what they call a design theory for information infrastructures. In their approach, they split the design of infrastructures into a *bootstrap problem* and an *adaptability problem*. The bootstrap problem refers to how to establish a new infrastructure. A central strategy for achieving this, according to the authors, is to draw up on an already existing installed base in the initial design, and then to expand the installed base with "persuasive tactics". The adaptability problem concerns the further evolution of a new infrastructure suggesting design should aim to simplify IT capabilities and modularize the infrastructure. In short, Hanseth and Lyytinen's (2010) five design principles argue for a gradual, iterative and explorative continuation of an installed base in order to establish and evolve a new infrastructure. Metaphorically, this approach to design can be described as *cultivation* or *growing* (Ciborra et al., 2000; Edvards et al., 2007; Aanestad and Jensen, 2011). As pointed out by Edwards and colleagues (2007: p. 7), infrastructures tend to grow in a distributed fashion: "Since infrastructures are incremental and modular, they are always constructed in many places (the local), combined and recombined (the modular), and they take on new meaning in both different times and spaces (the contextual). Better, then, to deploy a vocabulary of "growing," "fostering," or "encouraging" in the evolutionary sense when analyzing cyberinfrastructure." The growing metaphor gives a more apt description of a design process as an evolving process that is not under full control of designers, but one that can be facilitated. The metaphor of growing also gives a different temporal framing for the design process. Rather than only following a short temporal framing in terms of projects, large-scale collaborative systems should focus on continuous design adopting an long term temporal framing – 'infrastructure time' (Karasti et al., 2010). In broad strokes, as seen from the above discussion, the literature on information infrastructures has focused on characterising the *evolving process*, and come up with concepts, principles, and rules of thumb for designing (which are partly counter-intuitive compared to traditional design), rather than the concrete *work it takes to grow infrastructures*. What do designers actually do when they 'grow' infrastructures? And, who are the designers anyway?

More recent literature on information infrastructures have suggested the verb 'infrastructuring' as more fitting than the noun infrastructure, putting a greater emphasis on the continuous process of infrastructuring or how an infrastructure evolves through user's and designers' modifications, extensions, and usage over time (Bossen and Markussen, 2010; Parmiggiani et al., 2015; Pipek and Wulf, 2009). In line with Bossen and Markussen (2010), we will also in this paper adopt the notion of *infrastructuring* for "highlighting the ongoing work that sustains infrastructures" (Bossen and Markussen, 2010: p. 618). Hence, this is an analytical shift towards a process perspective of infrastructuring also underscores how design and use of infrastructures are intertwined (Pipek and Wulf ,2009) and how infrastructures become increasingly entangled over time (Parmiggiani et al., 2015). With regard to infrastructuring, we want to shift the focus from initial design work and initial usage, to the often more invisible maintenance work and repair work done in order to enact and re-enact infrastructures in organizations. Furthermore, we use the concept of *infrastructuring* to denote how *maintenance, design and use are inherently intertwined* in large-scale digital infrastructures. Hence, the underlying assumption here is that maintenance and repair work play a more significant role in infrastructuring digital platforms for collaboration than typically anticipated in practice and documented in existing infrastructure studies.

In the context of infrastructures, maintenance work and repair work broadly defined, comprises smaller tasks of re-configuration of IS, installing smaller upgrades of software, identity and access management, computer network management, server management, and writing smaller scripts and programs for transferring data between systems. In relation to information infrastructures it could also imply re-structuring, migrating, and meshing digital information, such as documents and excel sheets (Rolland et al., 2015). In modern IT-systems and infrastructures this happens constantly as part of normal day-to-day operations, and are not rare interventions and exceptions from the routine. Maintenance and repair work implies a shift in focus from designing new features to re-focus on the actual work that is undertaken to achieve sustainable infrastructures over longer periods of time. To paraphrase Jackson et al. (2012: p.9), this is to focus on what can be called "broken-world thinking", and a shift to focusing on "moments of maintenance and repair, rather than just moments of design and adoption, to the heart of CSCW thinking and practice". What do designers, users and others do when things break down, the systems stop working, or systems are not working according to the intention?

Maintenance work is well known to the CSCW community in terms of Orr's (1996) and Suchman's (1987) ethnographic studies of situated practices of Xerox copier maintenance and repair workers. Theses studies emphasised the often tacit and situated nature of knowledge and communities of practice as crucially important for problem solving, discrediting traditionalist views of 'pure' explicit knowledge in terms of procedures, rules, and all-embracing automation.

Maintenance work can also be related to the concept of 'articulation work' referring to how actors have to conduct additional work tasks in order to perform their 'primary work' (Gasser, 1986; Gerson and Star, 1986). Accordingly, Schmidt and Bannon (1992) from very early on recommended a focus on articulation work in CSCW as a key for understanding cooperative work settings and designing IT artifacts for supporting it. In relation to infrastructures the notion of articulation work has also been used in order to describe the work it takes for 'managing' such technologies (Sandusky, 2003). Arguably, then, maintenance and repair work can – at least to some extent be considered 'articulation work' that is needed in order to make infrastructuring work. Also, knowing-in-practice and the collaborative aspects of maintenance and repair as emphasised in Orr (1996) are also of high relevance to infrastructuring.

Infrastructuring processes typically involve a wide range of different interconnected systems and different communities of practice, as for example in the case of multinational oil companies (e.g. Hepsø et al., 2009) and large-scale hospitals (e.g. Hanseth et al., 2006). Henceforth, much maintenance and repair will necessarily involve how systems are interconnected and used across boundaries (Bowker and Star, 2000; Carlile, 2002; Lee, 2007; Levina and Vaast, 2005). Second, as many organizations today tend to outsource parts of their infrastructure and use various digital ecosystems, maintenance work in these settings would essentially be distributed and involve multiple actors both internal and external to the organization. As infrastructures become embedded with other infrastructures (Monteiro et al., 2013; Star and Ruhleder, 1996), the dynamisms and complexity of maintenance and repair work would change as well.

Ribes and Finholt (2009) discuss the tensions between development on the one hand, and maintenance on the other. Arguably, in most organizations there is a limited set of resources available implying that managers have a choice between developing new features or maintaining existing ones. In particular, Ribes and Finholt (2009) describe this as a characteristic of infrastructure as they are continuously developed and maintained over longer periods of time. Additionally, the authors point out that this tension is not necessarily only related to distribution of resources only, but more with how maintenance and repair work is valued by managers and organizations. The authors argue that while ideally development should "be tied to everyday maintenance, in practice, maintenance work is often invisible and undervalued" (Ribes and Finholt, 2009: p. 388).

3. Method and Case Context

GlobalOil is a privately owned medium sized company located in the western part of Norway. Currently, the company has approximately 300 employees located at nine different locations in America, Asia and Oceania, including larger offices in Houston, US, Perth, Australia and a HQ in Bergen, Norway. The company has over the past 25 years or so been through a remarkable journey with substantial organization changes, mergers, splits, and collaborations resulting in numerous advanced technological innovations used around the globe by some of the largest companies in the oil and gas industry.

The company started off in a small village on the west coast of Norway by a team of three friends in 1987. The local entrepreneurs started their business by cleaning various kinds of equipment used in the production of oil in the North Sea. In the 1990s the company won a contract with a major international oil and gas company on conducting technical inspections of equipment and the operations of maintenance. This spurred a considerable expansion through various mergers and acquisitions. Over the years, the company expanded internationally, and in 2011 the small start-up had grown to a corporation with 1800 employees with a HQ in Australia. At this moment in time the corporation spanned a wide collection of products and services including petroleum production with complete crew, engineers, equipment and floating rigs, subsea installations, maintenance and drilling. In close relation to one of the major companies in the oil and gas industry, several production technologies used in advanced drilling operations and oil and gas production in the North Sea have been invented. In 2012 parts of the company was sold to an American company. The remaining part was then a bit later on, in 2012, split in three different companies. The drilling part of GlobalOil was then re-established with approximately 200 employees mainly focused on selling advanced production technologies and the necessary expertise for installing and operating these around the globe.

Having expanded globally, with major sites in Norway and Australia, there was in the late 2009 increasing pressure for coordinating operations and projects between the two locations. Especially, there was an envisioned need for standardizing document management and archiving across projects typically involving employees located in both Norway and Australia. This included for example technical drawings and operational procedures explaining how to install and operate technical equipment on oilrigs and crucially important for both contractual and safety/environmental reasons as explained by a project manager of the engineering projects:

> [A procedure] includes a description of the equipment to be used and various authorizations, and then a detailed description of what and how to carry out the tasks. First testing of the equipment, then fill out a checklists, and then increase mud pump to 1000 gallons per minute [gpm], and so on. If you do not follow a correct procedure the customer has about 100-150 million dollar in expenditures and lost production for the next 40 years… [We] write this together with the customer. Procedures are very important – also because it is a way of securing our operations financially. So if something goes wrong it should be [a major international oil and gas company's] responsibility – and not ours.

Consequently, in order to have better control over such documentation as well as improving collaboration both within departments and across countries, the managing director of IT located in Norway decided to enterprise-wide system based on Microsoft's SharePoint 2007 software platform. Launched together with the Office 2007 package, SharePoint 2007 was part of Microsoft's digital ecosystem fully integrated with Outlook/Exchange server email and the Word text editor. The SharePoint software platform (2007) is built on top of Windows SharePoint Services (WSS) 3.0 that provides a full-fledged development platform based on existing technologies like ASP.NET 2.0 for developing web applications. In short, SharePoint 2007 provides a set of standardized features and templates covering six different functional areas: collaboration, portal, enterprise search, enterprise content management, business process & forms, and business intelligence.

On the large, there are four different communities of users intended for the new infrastructure in GlobalOil. First, project managers who are in charge of the engineering projects for the customers installing and testing the drilling equipment on oilrig. Second, there are engineers who invent and draw the drilling devices. Third, there are technical operators working at workshops in Azerbaijan and Norway assembling various drilling devices according to engineers' specifications. And fourth, a variety of more administrative personnel working on sales & marketing, IT, HR and health, environment and safety issues, as well as management.

The method used in this research can be described as interpretive case study (Klein and Myers, 1999; Walsham, 2006). The case of 'GlobalOil' was selected because of our keen interest in digital infrastructures based on software platforms in conjunction with the opportunity to study this in a particular turbulent business environment. In this respect, the case is especially relevant for researching issues of infrastructuring, because the organization during the last 10 years has undergone major organizational changes and subsequent transformations of a digital infrastructure as they have shifted to producing more advanced products and operating more on a global scale than before. This makes an "extreme example" which is well suited for theory development (Eisenhardt and Graeber, 2007).

A total of 24 in-depth qualitative interviews lasting from 1,5 to 2,5 hours have been conducted and transcribed. Some of the interviews were contextual interviews, involving interviewing while observing how the systems were used in the natural context of work whenever this was relevant. When this was the case, the transcribed interviews were supplemented with screenshots and notes on the use of the various systems. Central systems, including the engineers' PDM-system and the various SharePoint versions have been thoroughly demonstrated. Additional informal discussions have also been conducted while visiting the research site at different point in time. Here notes were written down shortly after or during the encounters. A total of six visits of two different sites both in Norway over a period of three years were conducted. Additionally, interviews of two consultants working on large-scale SharePoint projects elsewhere have been conducted in order to triangulate and further assess the information collected in the GlobalOil case. Four of the most central informants in GlobalOil have been interviews twice and even three times in order to follow up events and consequences over longer periods of time. Additionally, collections of relevant documents like a technical overview of the IT infrastructure, IT strategy, and general information of the company have also been part of the data collection.

Analysis of the data was done in a highly iterative fashion combining both concepts from literature and concepts emerging bottom-up from the data. Data analysis has been conducted following open coding and selective coding as inspired by grounded theory (Urquhart, 2012). However, this is not a grounded theory study as we were inspired by current literature on information infrastructures, and thus the analysis were highly focused and influenced by this body of literature. The emphasis on maintenance and repair work came in during the later stages of the process, as this issue is not much emphasised in current literatures.

4. Results

4.1 Vignette one: Maintenance work involved in innovating with the current infrastructure

After some smaller pilots with SharePoint version 2007 in 2009, a more comprehensive version was designed in a project starting in early 2010. External consultants who had expert knowledge of the selected SharePoint 2007 platform were hired, and a project was established together with developers from the internal IT department. The project also built on an on-going initiative to document and re-design new work processes taking the production of more advanced drilling equipment into account.

In this way, the project was also well aware of the importance and complexity of current work practices among project managers and engineers. The projects was organized in a multidisciplinary team as an agile development project (e.g. Dingsøyr et al., 2012), with one experienced engineer as a 'product owner' who would be especially involved in the design process and make decisions on behalf of the organization. Thus, developing a new document management system and support for global collaboration was approached as a traditional system development project rather than an infrastructure project.

In practice, this implicated that the project did not relate too much to the existing heterogeneous installed base of systems and practices through which the current documents were organized. Hence, after some months, the project turned into sever difficulties when trying to completely re-arrange the structure documents and the process of handling technical documents, by simply introducing the 'out-of the-box' features of the SharePoint 2007 platform.

In addition, the new comprehensive taxonomy for documents had been not tried out in practice before coded in the SharePoint platform, which led to a frustration among project managers. Furthermore, the out-of-the-box feature for searching did not comply with the requirements of the users since it was not possible to search in PDF-documents.

Accordingly, the development project had to re-design the basic structure for organizing documents. Although this type of customization can hardly be perceived as technically complex as such, it involved a total re-definition of how to structure and classify documents critical to how the company operates. As both engineers and project managers were used to a strictly hierarchical structure from exiting systems, like a niche information system called PDM for technical documents and drawings, the former Xerox DocuShare, and file servers, it also had consequences for these systems, their content, and users. Project managers had to change their practices and to stop to store documents on their laptops and on file servers located at different sites around the global organization. The PDM-system had to be integrated with SharePoint platform, to avoid that engineers had to use two systems for achieving technical documentations and drawings. As explained by one of the participants in the project this became impossible as technical drawings could not be stored on the SharePoint 2007:

> We tried to put all documents in SharePoint – that was our goal. However, we discovered that the SolidWorks drawings could not be stored in SharePoint. So, the drawings were left behind in PDM, and then, it was a longdrawn battle concerning where to store techncical documentation...whcih we eventually lost. Thus, the documents were left in PDM. They [the engineers] needed to keep drawings and technical documentation together… []… So, for now, we will leave it like this until we have done something with the new system [SharePoint]. (Informant_1, Engineer working with documentation)

Maintenance and repair work in this context was to re-define the meta-data structures for tagging documents, re-write the customized modules from the SharePoint 2007 platform to work on the SharePoint 2010 platform, and to customize the document library modules so that uploaded documents were structured in a similar way as a typical hierarchical file structure in addition to the normal flat structure. Moreover, a Document Control Centre was established in order to manage document flows between engineers, projects and external customers and suppliers. The Document Control Centre implemented systematic procedures for managing documents world-wide as well as more pragmatic handling of documents between the engineering community who continued to use the PDM-system and the projects which adopted the new SharePoint platform. In this way, the Document Control Centre, and the people working there became engaged in important repair work for making the SharePoint platform 'work' across contexts.

4.2 Vignette two: Maintenance work involved in stabilizing the infrastructure

GlobalOil was in 2012 bought and split into three different companies. Accordingly, a year after in 2013, the information infrastructure was abruptly split into different domains, and data, IT applications, and services were migrated and re-established in a new network domain. The new GlobalOil organization parted ways with their old IT department, and their strategy was first to completely outsource the IT function to an external company, the IT-Company. This strategy enabled the ability to quickly re-establish a minimalistic infrastructure for engineers and projects in the company. At the same time, GlobalOil continued to develop the new document management process in relation to the generic features of the SharePoint 2010 platform. Establishing new and more comprehensive document management was at this point an especially pressing issue, since GlobalOil had already started producing and offering the new advanced drilling installation that required more detailed documentation.

Soon after the split, the IT-Company was having severe challenges in migrating the old infrastructure and re-establishing it on a new network domain. Especially, the SharePoint 2010 platform and its integrations with neighbouring IT-systems were problematic. One such integration was the connection between the AD providing users access to sites on the SharePoint 2010 platform as well as the SolidWorks applications used by the engineers to design drilling installations. The SharePoint 2010 platform had over the last years become more entangled with the collaborative practices of engineers, project managers and also more administrative personnel such as HR and even the top managers had started to use it. In other words, the SharePoint 2010 platform was not only tightly integrated with a larger information infrastructure, but also socially embedded in the organizing of work. Consequently, the infrastructure problems outsourced to the IT-Company influenced document management practices and collaboration across engineers, workshops, and projects. Henceforth, one consequence was that project managers, engineers and other users of these main IT-applications needed extensive support and help in order to get accesses to their data and sites:

> They say: 'Can you no fix this? We really need access to this". This is continuously all the time, right. When users start changing things within the HR-system, and not in the Active Directory (AD) without telling us to update SharePoint, then it goes without saying that it becomes impossible for us. They do not see that there are more things behind than just adding information in the system [HR-system] (Informant_9, IT-architect)

Thus, re-designing the information infrastructure for the new GlobalOil company was far from an one-off project or task. Because of its complexity, with the many interdependencies between IT-applications, additional stakeholders such as the IT-Company, and still evolving the new work process for document management, this tended to be a continuous effort best described as repair work. More over, the SharePoint 2010 platform and the necessary collaboration involving project managers, engineers and others, were to a large extent reliant upon this repair work to take place.

In this situation, GlobalOil hired their own IT-personnel including some from the old organization having in-depth knowledge about the previous information infrastructure. In the following years then, there was continuous effort for repairing and extending the new information infrastructure. This infrastructuring work typically comprised of numerous situated experiments with small and incremental changes only, as for not upsetting the work of engineers:

> You do not want to have ten engineers not able to access their system for a week, so you take one and one PC or one and one user, and try out things. If it works, then you can implement the changes. (Informant_9, IT-architect)

An interesting aspect of infrastructuring work hinted on in the above quote, is the IT-architect's profound knowledge of engineers' practices and their local IT applications. Here, infrastructuring involves continuous repair work, which again requires in-depth knowledge about the collaborative practices of the communities using the information infrastructure-in-the-making. The lack of historical knowledge about the infrastructure in which SharePoint 2010 platform is an important part of, and of the collaborative work processes in the organization, made repair work cumbersome.

5. Discussion: Re-thinking Infrastructuring in Light of Maintenance Work

In this paper, we have conceptualized maintenance and repair work as a mechanism for producing both stability as well as innovation. This implicates infrastructuring across temporal scales, and how maintenance and repair work can facilitate scaling of infrastructures.

5.1 Maintenance work in infrastructuring across temporal scales

On of the most pressing issues of studying generic platforms and infrastructuring is the need for doing prolonged studies as social and organizational transformations differ over time, as well as recognizing how such technologies are continuously in development (Monteiro et al., 2013; Monteiro et al. 2014, Pollock and Williams, 2010). Karasti et al. (2010) has argued that infrastructuring entails simultaneously working with short-term issues as well as long-term issues. In order to extend the concept of infrastructure with a temporal dimension, Karasti et al. (2010) focus on distinguishing between 'project time' and 'infrastructure time'. Infrastructure time, the authors argue (p. 402), "involves taking account of the past and present in future plans and actions". Understanding the characteristics and role of maintenance and repair work is particularly relevant and important in this regard. Problems with different historical layers of existing installed base and on-going embedding with other infrastructures, are typically attempted solved through maintenance work. Hence, maintenance work requires a simultaneous focus on past, present and future. Drawing from the analysis of the case, we see that significant maintenance work is directed towards connecting an existing 'historical' installed base with the 'new' digital platform. In order to work across boundaries, involved actors need to have in-depth knowledge of both the historical layering of the existing installed base and the present challenges with enacting generic features of a digital platform like Microsoft SharePoint across different communities. For example, in the GlobalOil case, IT architects with long experience working with maintenance of the information infrastructure, use their experience-based knowledge about how different systems are interconnected, nuanced knowledge about the work of engineers and engineering projects, and continuous in order to envision a possible improved infrastructure for collaborating. This becomes increasingly an important competence as new modules and versions of the platform are to be configured and connected with the existing information infrastructure. In such cases, maintenance and repair work, as a realisation of working across boundaries and learning-by-trying becomes pivotal for connecting new artifacts to an existing installed base.

This also implicates that continuous maintenance and repair work is intrinsic to infrastructuring, and without this kind of work connecting new artifacts with the installed base, the infrastructure would run the danger of breaking apart. Arguably, this also illustrates that the recent turn in infrastructure studies focusing on the verb *infrastructuring*, rather than the noun infrastructure is a more apt for analysing the phenomenon under study. An infrastructure with no dynamics, no maintenance work - i.e. without infrastructuring, is a broken infrastructure reminiscing abandoned cities and buildings. Similarly, along these lines, infrastructuring platforms for collaboration arguably involve more continuous maintenance and repair work, than continuous design as outlined by Karasti and colleagues (Karasti et al., 2010).

In terms of infrastructuring phases, infrastructures tend to become increasingly entangled or embedded over time (e.g. Monteiro et al., 2013; Parmiggiani et al., 2015). What our study contributes to here, is that this 'entanglement' requires increasing amount of maintenance and repair work in order to sustain and evolve infrastructure. Over time, generic platforms become embedded with other infrastructures and practices of different communities. To this end, maintenance and repair work is highly socio-technical in nature, as it does not solely involve technically fixing the infrastructure when it breaks, but also involves translating and transforming work practices for achieving collaboration across contexts. Increased entanglement implies that a specific competence for conducting maintenance and repair involves in-depth knowledge of work practices as well as historical layers of the infrastructure. The 'maintenance work' as defined and illustrated in the case study above is relatively invisible in current notions of infrastructuring and design of large collaboration systems. Arguably, maintenance as a specific type of infrastructuring is especially important for enacting platforms in organizations as platforms are constantly changing and therefore needs to be 're-enacted' in local practices and infrastructures. In larger organizations, design of infrastructures involves organizing and mobilizing a wide range of distributed actors. Design processes need many different types of expert competence like knowledge about the work practices of engineers, user access management in SharePoint as well as the historical configuration of the domain network. Henceforth, distributing the responsibility across many actors introduces risks as well as possibilities for strengthening some areas of competence. With the increasing use of generic platforms and outsourcing of IT resources, then, there is a danger of organizing so that crucial knowledge about users, maintenance and design becomes fragmented. The typical split of development of new features done in a development project and a maintenance department is especially risky. Development of new features and maintenance cannot be done in isolation.

5.2 Maintenance work and scaling across communities-of-practice

A challenge for designing information infrastructures for collaboration is to take the 'non-local constraints' into account (Monteiro et al., 2013). This includes designing infrastructures across multiple local communities' practices and artifacts with potentially conflicting requirements and interests. Extant literature on infrastructures offers different insights on how these issues are dealt with and concepts for explaining how infrastructures are established – including gateways (Hanseth, 2001), generification work (Pollock and Williams, 2010), and different socio-technical aspects of integration and standardization (Ellingsen and Monteiro, 2006). In this paper, we have empirically as well as conceptually attempted to illuminate how various practices of maintaining and repairing contributes to infrastructuring – and henceforth potentially also have implications for the aforementioned insights and concepts.

First, in our analysis, we conceptualize maintenance work as boundary work bringing together different communities' different interpretations and interests through establishing boundary objects-in-practice. Thus, the boundary spanning-in-practice role of actors' doing maintenance and repair work is essential for establishing what has been referred to as gateways in infrastructure literature (Hanseth, 2001; Hanseth and Lundeberg, 2001). Gateways are often put forward as a promising way of 'growing' infrastructures building on an existing installed base (Edwards et al., 2007). As Hanseth (2001) declares and shows empirically in his study of computer networking in Scandinavia, gateways are "just as important as standards" for developing infrastructures. What the study presented in this paper adds to this, is that maintenance and repair work are intrinsic in establishing such gateways. In this perspective, gateways are an effect of maintenance work establishing viable ways of communicating and collaborating across boundaries. Arguably, this is even more important in relation to digital platforms like Microsoft SharePoint that as part of a larger ecology continuously evolve with new modules and versions, making maintenance and repair work necessary for enacting these new modules and versions in organizational practices. In this context, infrastructuring tend to comprise re-configuring and re-connecting new and old modules of an infrastructure to enable new ways of collaborating. Developing gateways in terms of smaller scripts transferring data and information across systems are typical results of maintenance and repair work – and not a large design project. This can be described as an on-going activity of maintaining the infrastructure, rather than a project designing new modules and infrastructures from 'scratch'.

Second, our study shows that generification work and processes has its limits. According to recent studies (e.g. Johannessen and Ellingsen, 2009; Pollock and Williams, 2010), generification work is essential in infrastructuring generic platforms in organizations. In the case, maintenance and repair work were also involved in generification through external consultants and gradual learning of which modules and features to omit from the generic platform. In this regard, maintenance work is a way of implementing what we might refer to as 'local generification', which is a prerequisite for enacting the new infrastructure in the organization. In organizations like GlobalOil, collaborative practices would always transcend the scope of the generic platform, delimiting the processes of generification. Especially, from a perspective of infrastructuring, generification processes will always be relevant for only parts of the infrastructure, making it vulnerable at its boundaries. Interestingly, because of generification processes, customizing is increasingly here directed towards utilizing the platform's generative features and not predominantly for re-aligning and working around its standardized features. The possibility for developing new modules on top of the generic platform enables user participation, improvisation, and exploration of potentially innovative applications (cf. Grisot et al., 2014).

Third, the necessity for socio-technical integration when infrastructuring collaboration has been argued elsewhere in the CSCW literature (Ellingsen and Monteiro, 2006). Similar to the hospital setting with multiple local laboratories and practices reported in Ellingsen and Monteiro (2006), infrastructuring platforms for collaboration involve comparable challenges with integrating across boundaries and deciding upon the granularity of integration. However, our study adds these insights that a substantial amount of the infrastructuring work involved in producing a feasible granularity and scope for integration – both socially and technically, is conducted not as pure design upfront during the official project (e.g. project time), but continuously established through maintenance and repair work. In sum, infrastructuring in terms of maintenance and repair work seems pivotal in scaling collaboration across communities-of-practice.

6. Concluding Remarks

In this paper, we submit that maintenance and repair work is not only intrinsic to sustaining the normal running and day-to-day operation of information infrastructures for collaboration, but in all phases of their development and use. Based on this, we draw the conclusion that maintenance and repair work is an essential mechanism for infrastructuring collaboration. While we would be cautious about generalizing this finding to all kinds of digital infrastructures, at least infrastructures that are substantially based on generic platform technologies across different communities-of-practice are likely to have this characteristic. Our motivation here has primarily been on attempting to theorize maintenance and repair work in relation to 'design' of infrastructures as our field work early on in the process showed puzzling evidence of both designers and users creatively extending the platform-based infrastructure during supposedly mundane tasks of maintenance. This, was in deep contrast to what we expected when a highly knowledge-intensive organization in a rapidly changing and difficult business environment wanted to rapidly – over night, introduced highly standardized platform for collaboration worldwide. In this respect, we agree with Jackson (2014) in that worlds of maintenance and repair should be seen as potential sources for innovation.

Future research could take on many different paths. In terms of studies, then, future research on infrastructuring should have a greater focus on generic platforms and how they are enacted in different collaborative practices and contexts. For example, most social media infrastructures including the so-called enterprise 2.0 for social collaboration internally in organizations are indeed generic platforms. Such generic platforms would also need maintenance and repair work – not only when they break down, but for innovating and enacting them in the first place.

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