Digitalized Industrial Equipment:
An Investigation of Remote Diagnostics Services

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Abstract

With the ubiquity of digitalization, digital convergence of applications, devices, networks and artifacts presents both challenges and opportunities for individuals, organizations and society. Physical artifacts that were not digital in the recent past are now increasingly becoming intertwined with digital components, providing them with digital capabilities. As a consequence, vast amounts of information that used to be invisible can now be captured, digitized and used in new places and novel ways. Organizations thus seek to innovate IT-enabled services based upon the flows of information across both internal and external organizational boundaries. Because IT-enabled services support organizational actors in communicating and collaborating both inside and outside the organizations’ boundaries, they can also assimilate and diffuse knowledge across these boundaries.

The thesis is a collection of five papers and a cover paper reporting an exploration of the role of digitalized equipment in boundary-spanning practices as a contribution to the design and implementation of IT-enabled services. Three embedded case studies of Swedish industrial organizations provide an opportunity to address the research question. The findings are based on studies of remote diagnostics services for industrial equipment enabled by remote diagnostics systems, an application family within ubiquitous computing.

The thesis illustrates that remote diagnostics systems have a profound impact on how organizational boundaries that were drawn as ‘crossovers’ are becoming less limited by constraints of time, space and the type of data shared. These systems permit workers at remote sites to gain access to information about external dispersed equipment and production processes. They also create new boundaries between entities that were not previously connected and across existing boundaries with new information and knowledge. This thesis gives insight into how such information sharing across boundaries may leverage multicontextual practices.

This thesis contributes to the existing literature with the development of a conceptual apparatus for understanding how embedded technology transforms boundary-spanning practices from a pure social activity to a boundary-spanning assemblage. Boundary spanning is an increasingly complex sociomaterial practice that fundamentally rests on technology as well as human competencies. The technology is deeply intertwined in the boundary-spanning activity as the sensors installed in the monitored
equipment serve as the remote technicians’ eyes and ears. Together, the technology and the technicians form a boundary-spanning assemblage.

While information systems research has called for attention to the ‘IT artifact’, this thesis underscores the importance of the characteristics of the specific technology and the profound effects it has had on its surroundings. In contrast to predominant ubiquitous computing research that mainly explores mobile applications, this thesis also shows how the increased embeddedness of IT makes technology an invisible but ever-present part of everyday work practices. Digitalized equipment with embedded technology thus raises not only novel opportunities but also novel challenges for both users and researchers.

We can design IT solutions today where people close to the technology have no access to or awareness of it. People can be monitored without visual cues revealing the monitoring. Furthermore, developing or using an IT-enabled service is not merely about developing/using a technology or a system; it also involves issues about the technology’s value creation, its ownership, competencies and customer relationships. IT and services should thus not be considered as separate and subsequent processes: they are deeply intertwined and mutual. This thesis thus suggests that digitalized equipment with embedded technology deserves critical scrutiny.
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Preface

This thesis is a collection of five papers and a cover paper. The collection of papers is placed directly after the cover paper. The following papers are included in the thesis:


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Chapter 1
Introduction

1.1 Background
Developments in information technology (IT) are rapidly changing the landscape for contemporary organizations. Advancements in ubiquitous computing, digital convergence, open source, Web 2.0, service-oriented architectures and other emerging digital technologies are re-shaping organizations, traditional industry boundaries and business models (Benner, 2010; Rothaermel & Hill, 2005; Tilson, Lyytinen, & Sørensen, 2010). Digital technologies thus play a central role in ongoing industrial transformations, and the ubiquitous presence of computers has been identified as a primary source of innovation that introduces novel organizing logics, products and services (Yoo et al., 2008b). With the ubiquity of digitalization¹, digital convergence of applications, devices, networks and artifacts presents both challenges and opportunities for individuals, organizations and society (Lyytinen & Yoo, 2002b). Physical artifacts that were not digital in the recent past are now intertwined with digital components that provide them with digital capabilities. In this era

¹ While digitization involves the technical process of encoding analog information into a digital form, digitalization goes beyond this and involves “the transformation of socio-technical structures that were previously mediated by non-digital artifacts or relationships into ones that are mediated by digitized artifacts and relationships” (Yoo, Lyytinen, & Boland, 2008a, p. 5).
of computerization, vast amounts of information that used to be invisible can thus now be captured and digitized (Yoo et al., 2008b).

While new kinds of information can be produced and used in new places and novel ways through IT, organizations seek to innovate IT-enabled services based upon the flow of information across both internal and external organizational boundaries (Lyytinen & Yoo, 2002b). Because IT-enabled services can support organizational actors in communicating and collaborating both within and outside the organization’s boundaries (Mathiassen & Sørensen, 2008), they can assimilate and diffuse knowledge across these boundaries. The ability to protect knowledge resources within organizational boundaries or to allow knowledge to flow across them has long been recognized as critical for organizations. This ability affects, among other things, organizational innovation and everyday work practices (Balogun et al., 2005; Levina & Vaast, 2005; Lindgren, Andersson, & Henfridsson, 2008; Malhotra, Gosain, & Sawy, 2005). When members of an organization cross internal and external boundaries to attain knowledge, it is called boundary spanning, and the actors involved are called boundary spanners (Leifer & Delbecq, 1978).

Contemporary boundary-spanning practices are typically supported by various IT solutions. IT eliminates the problem of distance, increases speed, provides universal access and cuts down on communication costs, enabling ‘cross-over’ practices within and between organizations (Hayes, 2001). On the other hand, IT has reinforced existing boundaries (Levina & Vaast, 2006). One reason for these mixed outcomes is that the extant research has paid little attention to differences between IT systems that enable boundary-spanning practices. Clearly, an inter-organizational transaction system within a supply chain (Malhotra et al., 2005) and a collaboration system supporting inter-organizational design work (Majchrzak et al., 2000) will have different effects on boundary-spanning practices.

With the rise of ubiquitous computing, physical equipment is embedded with digital components enabling it to produce novel forms of information, interact with other equipment and connect to the Internet. Information can thus be collected and shared in ways that were not possible before, which is drastically changing the conditions for boundary-spanning practices. These new conditions call for more detailed consideration of emerging forms of IT in relation to boundary-spanning practices (Lindgren et al., 2008; Orlikowski, 2007; Orlikowski & Scott, 2008).
The predominant ubiquitous computing research is concerned with mobility and the use of digital artifacts such as laptops and mobile phones (e.g. Abowd & Mynatt, 2000; Cousins & Robey, 2005; Henfridsson & Lindgren, 2005; Jessup & Robey, 2002); it pays sparse attention to digitalized equipment and the ways in which such digitalization shapes the contexts in which the equipment is immersed. While individual use of mobile technologies is of critical concern, ubiquitous computing also introduces novel organizing logics and changes on an organizational level, making the organizational context an interesting arena for studies of digitalized equipment (Lyytinen & Yoo, 2002a; Yoo, 2010).

This thesis addresses the significance of digitalized equipment and boundary-spanning practices in organizations, focusing on remote diagnostics systems, an application family within ubiquitous computing (e.g. Lyytinen & Yoo, 2002a). When digital sensors are embedded in industrial equipment to digitize the conditions of different components, new materiality properties are embedded as well. Addressability, sensibility and communicability are examples of such properties that differentiate digitalized equipment from its non-digital counterparts (Yoo, 2010).

Remote diagnostics systems collect, store and continuously analyze data about the state of the industrial equipment and help, for example, to determine when maintenance or other types of intervention are needed. These systems are often incorporated into a remote diagnostics service, where a service provider diagnoses customers’ equipment to prevent breakdowns. In transmitting digital representations over space and time for extensive analysis, the remote diagnostics systems have the potential to transform localized, manual boundary-spanning practices into complex, digitally mediated, organizationally and geographically distributed activities.

To date, studies of remote diagnostics systems have, for instance, focused on the architecture of these systems (Han & Yang, 2006; Qu et al., 2006), trust issues in the outsourcing relationship (Westergren, 2008) and remote diagnostics systems’ role in an overall e-maintenance solution (J. Lee et al., 2006). No studies have been conducted on forms of boundary-spanning practices that follow these systems as they extend the flows of information and knowledge across boundaries. This thesis posits that remote diagnostics systems have the potential to spawn new forms of boundary-spanning practices involving novel interactions among previously unconnected actors both within and outside a given organization.
1.2 Objective
Empirically, there is a lack of research studies that explore digitalized equipment in organizational contexts and their integration with IT-enabled services. Theoretically, digitalized equipment needs to be explored further in relation to boundary-spanning practices. The purpose of this thesis is therefore to investigate the role of digitalized equipment in boundary-spanning practices as a contribution to the design and implementation of IT-enabled services.

To fulfill this purpose, the following research question is explored in this thesis:

How do remote diagnostics systems affect boundary-spanning practices in IT-enabled service arrangements?

Because remote diagnostics systems are deeply rooted in issues of digital convergence, embedded technologies and the intertwining of digital and physical components, they offer a fruitful arena in which to examine how digitalized equipment shapes boundary-spanning practices. The resulting theoretical insights can be used to formulate guidelines for the design of IT-enabled services in terms of how to transform existing boundary-spanning practices when introducing remote diagnostics services. The study also adds to the stream of existing research an interpretation of remote diagnostics systems as forming a ubiquitous computing environment supporting new IT-enabled services.

Three embedded case studies of Swedish industrial organizations provide opportunities to address the research question. The findings are based on embedded case studies of remote diagnostics services of industrial equipment enabled by remote diagnostics systems. From an empirical point of view, service providers as well as customers are included in the study.

1.3 Outline
This thesis comprises a cover paper and a collection of five individual papers. The cover paper is divided into eight sections. Following this introduction, section two summarizes relevant research on IT and services in industrial organizations, IT-enabled services and ubiquitous computing environments. Section three describes boundary-spanning practices, which is the theoretical framing employed in this thesis. Thereafter, section four presents the research context and describes maintenance services in general, the specific remote diagnostics system investigated here and the three cases. Section five outlines the research
methodology. This is followed by section six, which summarizes the five research papers. Section seven discusses the findings. Finally, section eight presents practical and theoretical implications as well as directions for future research. After the cover paper, the collection of five papers follows. The papers are listed below in the order in which they will be discussed in the cover paper.


Chapter 2
Related research

2.1 IT and services in industrial organizations
The industrial setting has a long history of IT use. During the 1970s and 1980s, computerization took off as work began to be automated. By this time, the industrial use of IT in general and the skills of individual industrial workers in particular raised interest from Scandinavian informatics researchers (Dahlbom, 2003) from both the critical and the socio-technical traditions (Bansler, 1989). Within the critical tradition, issues of labor and workplace democracy were explored in industrial settings, for instance, in the Demos project (Ehn, 1988; Å. Sandberg, 1983), the Norwegian Iron and Metal Workers project (Nygaard & Bergo, 1975) and the DUE project (Kyng & Mathiassen, 1982). In the socio-technical tradition, industrial settings were also researched in studies of technical change, for instance, in the steel, coal and docks industries (Mumford & Banks, 1967; Scott et al., 1963).

Zuboff (1988) also contributed to this research field with her study of computerized industrial work. As traditional industrial work disappeared in favor of service-oriented work (Dahlbom, 2003) and computers began to penetrate all parts of human life, so did the industrial focus of informatics research become less sharp (J. Holmström, Wiberg, & Lund, 2010). However, even though the industrial setting has not received much attention from informatics research during the last decade, the industrial use of IT has developed beyond pure automation. The interest
in studying IT design, use and innovation in the industrial context has thus grown as these areas have been shown to pose a host of interesting questions from an informatics point of view. Westergren (2010) examines contextual factors influencing an industrial open innovation project; Wiberg (2010) reports on operators facing a complex interaction challenge when monitoring key industrial processes; Rönnbäck, Holmström and Hanseth (2007) explore IT adaptation challenges in the process industry; Holmström and Tetzlaff (2009) analyze the enabling and inhibiting impacts of IT on lean manufacturing in a study in the pulp and paper processing industry; Nylén (2010) investigates IT as an enabler for open innovation systems in a manufacturing company; and Sandberg (2010) explores an IT innovation project within the mining industry. All of these studies reveal industrial contexts as sophisticated IT settings that host many interesting issues for informatics researchers.

Contemporary industrial organizations face challenges of how to deploy and adapt to the integration of equipment, computers, communication technology and the Internet, which have the potential to change products as well as production processes. A large body of research in the technological change literature has explored incumbent firms’ responses to radical technological innovations (Benner, 2007). These innovations can require an organization to make major changes in strategy and develop entirely new sets of knowledge and capabilities (Tushman & Anderson, 1986). However, existing internal capabilities within organizations can impede established firms’ responses to technological innovations (Benner, 2010).

The use of IT in industrial organizations has now evolved towards more extensive automation of the production process. Computerization allows sensors to obtain real-time production data. By means of these sensors connected in computer networks, the production flow can be monitored by operators at a distance, detached from the plant floor (Kallinikos, 2001). As discussed by Zuboff (1988), by the 1980s, whole industrial processes were no longer controlled through the physical presence of workers on the shop floor. Instead, they are controlled at a distance via information on a computer screen representing the process. While Kallinikos (2001) and Zuboff (1988) focus on the digitalization of the production process and process monitoring, this thesis concerns the digitalization of equipment and product monitoring.

Fierce global competition pushes industrial companies to seek constant renewal and more efficient production methods. Due to progress in manufacturing technologies, which have enabled companies to produce goods with life cycles that can last for several decades,
manufacturing companies seek to renew their business, for example, by developing additional services with steadier revenue streams. Industrial customers are also becoming more professional and often seek to outsource non-core functions and concentrate on their core activities (Matthyssens & Vandenbempt, 1998). This has opened up a market for business-to-business services, where a company provides services to other companies. For manufacturing companies, services related to the use, maintenance and operation of the goods that are produced constitute a growing part of their businesses (e.g. Oliva & Kallenberg, 2003; Phillips, Ochs, & Schrock, 1999; Slywotzky, 1996; Slywotzky & Morrison, 1997; Wise & Baumgartner, 1999). With the use of IT, industrial companies seek innovative solutions that can support their service production. Remote diagnostics systems comprise one such IT solution that supports novel maintenance services.

2.2 IT-enabled services

The modern economy is transforming into a service-based economy that is enabled by – and often dependent upon – IT (Barrett & Davidson, 2008; Kallinikos, 2006). Historically, this topic has not raised much interest from IS research, but it is attracting a growing interest. For instance, in 2008, the IFIP Working Group 8.2 conference was dedicated to ‘IT in the Service Economy’ (Barrett et al., 2008) and MIS Quarterly will publish a special issue on ‘Service Innovation in the Digital Age’ in 2012.

However, it should be noted that ‘IT-enabled services’ is a broad term capturing a variety of services in different areas. The proceedings of the IFIP 8.2 conference on ‘IT in the Service Economy’ cover services ranging from call center services to electronic trading services and the use of mobile phones for health care services (Barrett & Davidson, 2008). The manufacturing industry constitutes another area where IT contributes to an increase in services as opposed to the traditional product focus (Oliva & Kallenberg, 2003). This area is of specific interest for this thesis.

For manufacturers, products have turned into a platform enabling integration of a comprehensive set of services to meet customers’ needs (Alter et al., 2008). However, the delivery of services is qualitatively different from the delivery of products as it lacks a concrete artifact that mediates customer relationships. Service production instead involves an ongoing exchange of intangible assets between a provider and a customer (Grönroos, 1990; Quinn, 1992). The process of changing from a product-oriented to a service-oriented business is, however,
surrounded by obstacles as there are hurdles to overcome in terms of economic potential, competence and strategy/organizing (Oliva & Kallenberg, 2003).

Despite those hurdles, IT use in services has become a key activity for further service innovation (Edvardsson et al., 2000), and IT is used both for developing totally new service concepts (Zeithaml & Bitner, 2000) and for redesigning existing services (Berry & Lampo, 2000; Grönroos, 2001). The quality and the characteristics of IT undoubtedly influence the quality and the characteristics of services. For instance, IT-enabled services may take on characteristics typically associated with products, such as storability and separation of production and consumption of the service (Barrett & Davidson, 2008). With the use of IT, services are being automated in the same way that production of goods was automated with great success (Kuschel, 2009). IT has, for instance, enabled new self-services such as Internet banking, which have reduced the necessary manual tasks for the service provider. Remote customer order entry and follow-on customer service systems are two additional examples of self-service systems (Lyytinen & Rose, 2003). Orlikowski & Schultze (2004) also discuss the use of IT as an enabler of automated self-services, where service provision can take place without direct involvement of the service provider.

In looking beyond the traditional automation of services in the form of self-service systems, this thesis explores digitalized equipment as a platform for customized services. Products embedded with sensors are not merely present in industrial settings. For instance, a contemporary vehicle is embedded with sophisticated computing capabilities (Svahn, Henfridsson, & Yoo, 2009). In his investigation of vehicle services, Kuschel (2009) argues that vehicles serve as a matured ubiquitous computing environment, where sensors and computer components optimize the driving experience without the driver taking notice of the technology. Digitalized industrial equipment is in a similar way equipped with sensors and computer components that serve to optimize the uptime of the equipment.

However, even though ubiquitous computing offers new opportunities for service automation, Kuschel (2009) shows how vehicle manufacturers extend equipment functionalities rather than addressing customers’ use of the vehicle. A challenge for manufacturers is thus to utilize IT to improve services by attending to their individual characteristics. While Kuschel’s (2009) work contributes important insights on consumer services, this thesis turns its attention to business-to-business services enabled by digitalized industrial equipment.
Digitalized artifacts add a new dimension to service relationships as the embedded sensors can become the eyes and ears of remote service providers (Gershman & Fano, 2005) who can access real-time data and offer seamless services to customers (Gershman & Fano, 2006; Kourouthanassis & Roussos, 2003). With sensors embedded into equipment, service providers are no longer dependent upon users to enter all of the necessary information. In the consumer market, Fano and Gershman (2002) expect ubiquitous computing to transform aspects of services, such as the role of location, the scope of the service and service duration and frequency. Service providers will be able to make the location of the customers the location of their business, which will foster new remote service providers offering services to distant customers.

2.3 Ubiquitous computing environments
Two decades ago, Weiser (1991) envisioned ubiquitous computing\(^2\) as the information technology for the 21\(^{st}\) century. In contrast to other types of IT that are designed to bring the computer to the foreground, ubiquitous computing is designed to make technology vanish into the background. Weiser’s idea was an environment where IT would be embedded in various devices to support everyday life.

A common description of ubiquitous computing is that it integrates stationary, mobile and embedded technologies into heterogeneous IT environments (Andersson, 2007) such that processors and sensors can be integrated into everyday objects, creating a digitalized artifact where the technological device disappears. Yoo (2010) identifies programmability, addressability, sensibility, communicativity, memorizability, traceability and associability as materiality properties that are added when non-digital artifacts are embedded with computing capabilities. Most digitalized artifacts seamlessly collect data about the states of products and processes in the environment, which can then be transferred through space to other settings or retained over time for intelligent analysis and response. Moreover, these properties enable “light weight” interactions between actors and environments where both the environment and the actor can be computationally and data rich, thus offering a new level of intelligence in interactions (e.g. Lyttinen & Yoo, 2002a).

\(^2\) Also known as pervasive computing or nomadic computing (Lyttinen & Yoo, 2002b; Satyanarayanan, 2001).
A frequently cited paper in IS research that gives an overall view of environments with digitalized artifacts, or ubiquitous computing environments, is a research commentary published by Lyytinen and Yoo (2002b) in *Information Systems Research*. In this paper, ubiquitous computing environments are characterized as a heterogeneous assemblage of integrated socio-technical elements. As depicted in figure 1, three essential features of a ubiquitous computing environment – mobility, digital convergence and mass scale – influence and enable development of both infrastructure and services.

![Figure 1. Ubiquitous computing environments (Lyytinen & Yoo, 2002b)](image)

Convergence refers to the integration of IT into different artifacts enabling computer capabilities to be embedded in the physical environment. Mobility refers to movement of users, IT artifacts and services across and between different pieces of equipment. Mass scale describes the growing volume of services enabled by the availability of ubiquitous computing environments at a global level. Ubiquitous computing environments support individuals as well as organizations, and they have implications on individual, team, organizational and inter-organizational levels (Lyytinen & Yoo, 2002b). In this thesis, the term ‘remote diagnostics systems’ refers to the infrastructure of the ubiquitous computing environment, and ‘remote diagnostics services’ refers to services enabled by this infrastructure.

Over the last two decades, ubiquitous computing has been the subject of a large amount of research exploring different topics, often employing visionary experimental approaches. Different forms of technologies, such as wearable computers, embodied computing, mobile phones, laptops, wireless PDAs, collaboration environments, videoconferencing, pagers and email, have been studied by ubiquitous computing
researchers (e.g. Abowd & Mynatt, 2000; Fano & Gershman, 2002; Yoo & Lyytinen, 2005). During the last decade, ubiquitous computing started to attract attention from researchers in the information systems (IS) field, and the topic has been presented and discussed in dedicated conferences and journals. For instance, in 2005, *Information & Organization* published a special issue on the social impact of ubiquitous computing in which the included papers explored different ubiquitous computing environments. Henfridsson and Lindgren (2005) investigate how mobile phone use can be supported in cars. Sørensen and Pica (2005) examine the British police force’s use of mobile technologies such as personal radio communication, mobile phones and mobile data terminals. Finally, Cousins and Robey (2005) explore the use of laptop computers in a mortgage finance corporation. In the same year, *Information Systems Management* also published a special issue on ubiquitous computing. In the first article, Jarvenpaa and Lang (2005) report how individual users in different countries experience their interactions with mobile phones. Garfield (2005) explores the acceptance of tablet PC technology across a diverse group of companies. Banavar et al. (2005) present a visionary context ecosystem involving positioning devices such as radio frequency identifier (RFID) tags and wireless personal digital assistants. Aaltonen et al. (2005) investigate a prototype of a mobile phone system that uses different context information. Chen and Nath (2005) emphasize organizational culture as critical for mobile workforces. Finally, Andersson and Lindgren (2005) report on a heterogeneous road haulage system that integrates mobile and stationary technologies to support road haulage organizations. As this system includes embedded sensors that can record performance parameters from the truck, it was viewed as enabling detailed and timely follow-up on field activities. The paper identifies the integration of mobile and stationary workers and systems as critical in ubiquitous computing environments. In 2006, *Information Systems and e-Business Management* presented a special issue on ubiquitous computing environments with two articles. First, Singh et al. (2006) propose an architecture for a computing platform supporting mobile users. Second, Al-Hammouri et al. (2006) present three prototype examples and discuss challenges emerging due to the mobility of applications and users.

Dedicated conferences and workshops have also provided arenas for IS researchers to discuss ubiquitous computing (Lyytinen et al., 2004; Sørensen & Yoo, 2005). At the IFIP 8.2 conference 2005, the track exploring the organizational impact of ubiquitous computing concerned wireless laptops (Martins & Jones, 2005), personal digital assistants
(Kakihara, 2005; Tapia & Sawyer, 2005), a heterogeneous road haulage system (Andersson, Lindgren, & Henfridsson, 2005), a library RFID system (Ramchand, Devadoss, & Pan, 2005), wireless communication (McKnight, Sharif, & van de Wijngaert, 2005) and portable computers (Wiredu, 2005).

Studies of RFID systems and heterogeneous transport systems differ from the major focus on personal mobile devices in the sense that these solutions incorporate more than just a mobile artifact. Kietzmann (2008) explores a mobile RFID-based system used by a mobile security guard company. Small tags were attached to various elements in the environment patrolled by the guards. The guards carried a mobile transceiver that communicated with the tags once they were in close proximity. The guards could then select a message on the reader that, together with the tag identification, was sent to the office. Thereby, the company could keep track of the mobile guards’ location and the status of each element. The system thus facilitated insights into mobile work that were previously not possible or required. Lee and Shim (2007) examine the use of RFID in the healthcare industry. In hospitals, the use of these sensors is on the rise, and they are primary used in inventory tracking systems and patient identification systems. While this study reveals very few details of the studied technology, it indicates that the perceived value of the technology was related to the reduction in error rates and improvement in customer service resulting from its use. Ramchand et al. (2005) explore a prototype of a library RFID system, where small chips are embedded in the spine of a book, enabling self-serve loan and return processes. The authors conclude that this system helps with automating previously manual tasks, liberating time for the library staff that can be used to help people find information. In a number of papers, Anderson, Lindgren and Henfridsson (Andersson, 2007; Andersson & Lindgren, 2005; Andersson et al., 2005; Lindgren et al., 2008) report on a road haulage system. This system contains sensors embedded in trucks that, for instance, give feedback on driving performance and fuel consumption. However, their studies report only useless sensory information as no meaningful interpretation of the acquired data could be made (Lindgren et al., 2008). The case organization’s use of this system thus did not meet the goals of the vehicle manufacturer, who viewed the system as a tool for improved customer relations and product development. The manufacturer and the customer thus did not share an idea of the system’s use and value creation. The study instead reveals frustrations and difficulties related to
the use of embedded systems and calls for further exploration of this topic.

Overall, ubiquitous computing in IS research has primarily explored mobile technologies, and little emphasis has been put on embedded systems, digital convergence and sensor technologies. This lack of attention has resulted in a growing interest and attention to digital convergence and digitalized artifacts (Svahn et al., 2009; Yoo, 2010; Yoo et al., 2008b).

Remote diagnostics systems build upon digitalized equipment with embedded sensors. These systems automatically collect and transfer data across organizational boundaries to allow for remote diagnostics of the equipment’s condition. Thus, remote diagnostics systems are, by definition, enablers of boundary-spanning practices and should be interpreted from that perspective. The boundary-spanning capability of ubiquitous computing applications in general has been observed as they can blur physical, social and temporal boundaries of an organization (Henfridsson & Lindgren, 2005; Lyttinen & Yoo, 2002b). However, the major promise is the capability to (more or less) automatically collect a broad range of sensor-based information about distributed activities in real time (Lindgren et al., 2008). Consequently, the issue of digitalized artifacts and their new digital materiality properties is of critical concern from a boundary-spanning perspective. While the issues of mobility and the blurring of time and space boundaries are well explored in IS ubiquitous computing research, digitalized equipment as an enabler of boundary spanning is still rather unexplored.
Chapter 3
Theoretical background

3.1 Boundary-spanning practices
Information has for several decades been essential to organizations that serve as consumers, managers and purveyors of information (Feldman & March, 1981). Accurate information is essential but relatively difficult to gather as boundaries hinder the free flow of information (Tushman & Anderson, 1986). Organizations are fragmented by such boundaries, which serve as demarcations of varying and incompatible tasks and systems. Leifer and Delbecq (1978) define a boundary as the demarcation between one system and another that protects the members of the system from extra-systemic influences and regulates the flows of information, material and people into or out of the system. As employees engage in their tasks, boundaries emerge, languages diverge and logics change to increasingly separate the fields of practice. At the same time, an organization’s ability to create, transfer and integrate knowledge from diverse sources is viewed as a key competence (Kogut & Zander, 1992). Consequently, organizations increasingly develop and engage in boundary spanning both internally and externally. In general terms, boundary spanning can be described as an activity of making sense of peripheral information to expand local knowledge in a given organizational context (Lindgren et al., 2008).

Lindgren, Andersson and Henfridsson (2008) identify two distinct perspectives on boundary spanning in the literature: organizational
innovation and everyday work practices. The innovation perspective views boundary spanning as essential for organizational renewal, and it aims at linking new, typically external, information to prior knowledge. The work practices perspective views boundary spanning as essential to learning and typically recognizes boundary spanning across internal boundaries of the organization aimed at situating information in the context of local work practices. However, the authors argue that this distinction is blurred in ubiquitous computing environments, as these environments enable collection and transfer of information that is useful for organizational learning as well as innovation.

To deal with the difficulties of gathering and diffusing information across organizational boundaries, boundary roles evolve in the organization (Cohen & Levinthal, 1990; Tushman & Anderson, 1986). The individuals engaged in these roles are described as boundary spanners, and their role and behavior have received considerable attention in the extant literature (Levina & Vaast, 2005; Tushman & Anderson, 1986). A boundary spanner is a person operating at the boundaries of an organization or engaging in a task relating the organization or a unit of it to external elements (Leifer & Delbecq, 1978). However, knowledge sharing is not merely performed by dedicated boundary spanners. All persons in an organization can, and need to, engage in boundary spanning as information is exchanged between the organization and its environment (Balogun et al., 2005).

While this thesis is anchored in the boundary-spanning field, it should be noted that there are other overlapping fields as well. The field of inter-organizational systems is mentioned in the fifth paper, and this field focuses on systems shared across organizational boundaries. However, as the boundary-spanning capability is not the primary interest in this field, it is not explored further in this thesis.

### 3.2 IT and boundary spanning

The interplay of IT and organizations has been of interest to researchers for several decades as IT has brought about significant changes in organizations (Zammuto et al., 2007). Platform organization (Ciborra, 1996) and loosely coupled organization (Boudreau & Holmström, 2007) are two perspectives on the interplay of organizations and IT. Rather than focusing on IT’s effects on organizational forms and structures, this thesis concerns the interplay of IT and organizational boundary-spanning practices. Although boundaries may be vague, they are demarcations of one external and/or internal system from another.
Various kinds of information systems support boundary spanning as IT artifacts can form one class of boundary objects when they are shared across two or more organizations, units, or social worlds. They enable or constrain boundary spanning as they permit or prevent the efforts of organizations’ members to share information across functional, geographic and temporal boundaries (Hayes, 2001). As information becomes increasingly digitized, it can be shared instantly; geographic distance becomes irrelevant, enabling distributed collaborations; and improved access generates new forms of boundary spanning (Fountain, 2001). For example, digital ‘capabilities’ such as email, Internet sites, and groupware provide access to multiple sources of information over a distance and consequently expand boundary spanners’ capabilities (Yan & Lewis, 1999). Therefore, many studies emphasize the ability of IT’s enabling or enhancing to span internal as well as external boundaries. Several studies show such positive enabling or enhancing impacts on boundary spanning. For example, Levina and Vaast (2005) find that email and intranets allow actors to share new information across boundaries within and between organizations. In addition, Pawloswki and Robey (2004) show how enterprise-wide human resources systems and financial systems allow knowledge to flow across the boundaries that separate work units within organizations. Barrett and Walsham (1999) illustrate how the introduction of a computerized trading system offered opportunities for organizations to span external boundaries and access new markets.

The overall impact of IT on communication and knowledge sharing across boundaries, however, has been mixed, as IT has also been found to reinforce existing boundaries. For instance, Levina and Vaast (2006) describe how an intranet application transformed a close relationship between teams within an organization into an objectified relationship with increased dissatisfaction. Moreover, in their study of a global bank’s intranet, Newell, Scarbrough and Swan (2001) find that the intranet reinforced existing functional and national boundaries. Likewise, Schultze and Boland (2000) find that a knowledge management system with an electronic news feed reinforced pre-existing intra-organizational boundaries in a manufacturing firm. In a study of an electronic library system that was implemented to enhance knowledge transfer between communities, Goodman and Darr (1998) find that the system did not manage to overcome differences across the communities. The pre-existing boundary was thus reinforced as the community members
turned back to their own communities rather than seeking to share knowledge with other communities. Similar results were seen in an inter-organizational setting in Schultze and Orlikowski’s (2004) study of an IT-enabled self-service system that altered the nature and quality of information shared by the participants and reduced the frequency of their interaction.

In the boundary-spanning literature, IT use for knowledge sharing across boundaries is characterized as a change from embodied relationships to objectified relationships (Levina & Vaast, 2006; Schultze & Orlikowski, 2004). While this change, on one hand, expands the boundary spanners’ capabilities and enables knowledge to flow across both internal and external boundaries, it can also lead to reinforcement of pre-existing intra- and inter-organizational boundaries. Table 1 illustrates the contradictory findings for the effects of IT use in boundary-spanning practices.

<table>
<thead>
<tr>
<th>IT helps spanning boundaries</th>
<th>Internal boundaries</th>
<th>External boundaries</th>
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<tbody>
<tr>
<td></td>
<td>Newell, Scarbrough and Swan (2001)</td>
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<td>Schultze and Boland (2000)</td>
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<td></td>
<td>Goodman and Darr (1998)</td>
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Table 1. Examples of contradictory consequences of IT on boundary spanning

Despite significant differences between the internal and the external perspectives regarding IT’s impact on boundary spanning, both have paid little attention to the specifics of the information technology. According to Lindgren et al. (2008), the external perspective basically views IT as a tool that provides particular information processing capabilities that are subject to managerial control, and the internal perspective tends to focus on how IT or boundary objects become resources in local meaning creation. As the table above reveals, the findings are mixed. Moreover, a distinct internal or external perspective may also lead to insufficient attention to differences between types of IT
artifacts and the potential of new boundary-spanning opportunities and challenges emerging with new technologies (Lindgren et al., 2008).

The relationship between IT and organizing represents a long-standing issue in IS research (Leonardi & Barley, 2008). While the importance of both the technology and the social factors is generally acknowledged in the IS literature (Leonardi & Barley, 2008; Orlikowski, 2002), there is a tendency for researchers to favor one or the other (Leonardi & Barley, 2008; Monteiro & Hanseth, 1996). Several papers recognize a tilt towards the social factors and thus call for attention to the IT factors (e.g. Benbasat & Zmud, 2003; e.g. Orlikowski & Iacono, 2001; Orlikowski & Scott, 2008; Weber, 2003). While IT provides materiality capabilities that allow not only for improvements but for radically new ways to perform an activity, Leonardi and Barley (2008) argue that we need to go beyond the communication tools and sophisticated databases that have attracted so much attention in research. Rather than only capturing technologies that primarily enable people to do current tasks in more efficient or effective ways, the research agenda should also be to study technologies that produce novel forms of information as these may have broader implications for the nature and organization of work (Leonardi & Barley, 2008). In order to meet this goal, we do, however, need to be specific about the technology and its role in our analyses (Orlikowski & Iacono, 2001). Digitalized industrial equipment offers a fruitful arena in which to study technologies that produce novel forms of information, and for the purpose of this thesis, the level of specificity of the technology targets the remote diagnostics systems and the associated service leveraged by the system and its users.
Chapter 4
Research Context

4.1 Maintenance services for industrial equipment
A major part of the innovations in after-sale services is driven by developments in IT (Agnihotri, Sivasubramaniam, & Simmons, 2002), and manufacturing companies are devoting much effort to improving services related to customer uptime, which has shown to be a crucial factor for success (Armistead & Clark, 1991). Failures usually cause large economic losses in the form of lost production and may be hazardous in terms of safety and environment. The losses and hazards can be kept to a minimum if failures can be predicted and fixed on time by performing the required maintenance tasks or replacing parts.

Tsang (2002) divides maintenance into four approaches: run-to-failure, preventive maintenance, condition-based maintenance and design improvement. With a preventive maintenance approach, the aim is to replace items before a failure occurs, which can be contrasted with a run-to-failure approach, where only routine servicing is performed on an item until it fails. Condition-based maintenance is one type of preventive maintenance approach where the equipment’s condition is monitored. Performance-parameter analysis, vibration monitoring, thermography and oil analysis are some condition-monitoring techniques that enable preventive maintenance. With these technologies, the condition of the equipment can be monitored while it is in operation. The last maintenance approach is design improvement, where the design of the
equipment is modified to minimize recurring failures. Remote diagnostics services build on a preventive maintenance approach where components are replaced before the equipment breaks down. A remote diagnostics system enables condition-based maintenance where certain parameters in the equipment, for instance the vibrations of the bearings, temperature and speed, are monitored. Preventive maintenance was traditionally a field-based service organized around scheduled maintenance. However, remote diagnostics systems enable service providers to monitor the equipment from a distance.

4.2 Remote diagnostics systems
The use of ubiquitous IT capabilities in industrial production environments enables continuous condition-based machinery and production process monitoring. Remote diagnostics systems rely on the accuracy, timeliness, volume, multi-dimensionality and extended time-spans of new forms of digital data representing production states and objects. They collect, store and continuously analyze data about the state of production equipment and processes and help, for example, to determine when maintenance or other types of intervention are needed. They can not only automate significant portions of component-based performance monitoring but can also help diagnose problems or provide early signaling of potential problems (Biehl, Prater, & McIntyre, 2004). These systems are organized around rich forms of digital data gathering and exchange that allow for extensive, real-time, model-based computations (Simmons, 2001).

Remote diagnostics systems are made up of collections of heterogeneous technologies: sensors that collect data, networks that transmit them into a centralized repository; and analytics and operational rule systems that store and retrieve the data, analyze them, visualize them and make recommendations, generate alarms or launch responses. The sensors are distributed among critical physical components throughout a plant or an industrial network (Han & Yang, 2006). Depending on which types of sensors are installed, the remote diagnostics system can, for instance, collect data on vibrations of bearings or temperature, pressure and speed. By monitoring such data, it is possible to detect problems in the equipment early on.

The users of remote diagnostics systems are the preventive maintenance technicians who analyze the data presented by the system and make final recommendations. These technicians can collect additional data via operators and maintenance technicians to refine the recommendations, and they are responsible for presenting these
recommendations to the maintenance technicians working in the plants. The remote diagnostics systems can be implemented internally within a plant, where dedicated technicians are responsible for the diagnostics. However, this thesis focuses on the use of remote diagnostics systems in IT-enabled services: the remote diagnostics services. These services are based upon the remote diagnostics systems and the remote preventive maintenance technicians who use their skills and knowledge to make recommendations on the equipment’s maintenance. These services are provided to a multitude of customers by a service provider physically distant from the customers’ plants.

These services have led to a centralization of maintenance that was previously locally arranged. Remote service centers are organized globally and monitor and diagnose a large number of pieces of distributed industrial equipment and their components across multiple organizational boundaries. The systems have generated new insights, like brokering leading maintenance practices data and new maintenance rules. Moreover, they increase the information and knowledge intensity of maintenance work as remote technicians can analyze multiple datasets in complex ways at small additional cost. The technicians can also focus on proactively diagnosing problems by learning from past cases. The maintenance services become knowledge intensive and the technicians can prevent failures through rule-based decision making or statistical sampling and data mining (Kuschel & Ljungberg, 2004; Tolmie et al., 2004). Not surprisingly, industrial organizations have widely adopted remote diagnostics services as the cost of sensors has decreased and their networking capability and environmental adaptability has increased. Figure 2 presents a general overview of how maintenance is organized with remote diagnostics services.
Remote diagnostics systems can be viewed as harbingers of a new distributed and networked knowledge-intensive industrial organization that reorganizes production functions and their control geographically based on the creation and distribution of new knowledge-based operational skills. Moreover, they foster novel ways to organize production and maintenance that separate local information from its origins and make it travel to permit centralized technicians to act from a distance. They establish unprecedented knowledge-based routines that separate technicians from the components they monitor in time, space and industrial context. Because remote diagnostics systems are enabled by sensor technologies embedded in industrial equipment, they offer a fruitful arena to examine how digitalized industrial equipment and increasingly embedded features afforded by IT shape boundary-spanning practices.

4.3 Research sites
In 2002, I participated in an exploratory study of remote diagnostics services at MacGregor Cranes (MGC). This study showed that the company faced unexpected challenges in the development of its remote diagnostics services but also possibilities that were so promising that the company could not afford to abandon the service and the remote diagnostics system. The results were interesting, and the study also revealed that existing research had paid sparse attention to organizational implementations of ubiquitous computing applications and, more specifically, remote diagnostics systems (Jonsson, Westergren, &
Holmström, 2008). These findings triggered my interest, and the study came to serve as a point of departure for my PhD project.

The study at MGC was conducted as part of the larger project entitled Industrial City 2.0. This project was already running when I joined, and the project leader had established contact with a number of industrial organizations with a common interest in embedded sensors. All organizations in the project were represented in a project board, which met on a regular basis and discussed activities, results and common interests. The first two case studies were conducted as parts of Industrial City 2.0, and the project came to serve as an important base for subsequent study ideas.

Industrial City 2.0 ended in 2004, but the valuable insights and experiences gained from this project served as an important base for a new and larger project: ProcessIT Innovations. My interest in remote diagnostics systems and industrial contexts fit well into ProcessIT Innovations, and the third case study was conducted within this project. This project also served as a valuable base for acquiring new knowledge as findings and methods could be discussed with representatives from different academic fields as well as representatives from industrial organizations.

This thesis covers three different case studies. The first one is a single-case study, while the other two are embedded case studies with multiple units of analysis. The following sections will present the units included in each case.

4.3.1 Case 1
Together with a fellow researcher, I first came into contact with MGC in September 2002. We attended a meeting at the company’s main office, where representatives presented their visions of a remote diagnostics system with corresponding services. This meeting served as a start-up of the first case study in this thesis. At that time, the remote diagnostics system had not yet become a reality, and our study focused on the preconditions for the development of a remote diagnostics system and related services. The initial project ended in 2003, but we conducted a number of follow-up interviews to continue tracking the development process.

MacGregor Cranes
MGC was founded more than 100 years ago to manufacture industrial products. In the early 1960s, the first cargo-handling crane was introduced, and the company soon became established as the leading
brand in this field. Over the years, MGC has delivered more than 8,000 cranes. The company is still a world leader in this sector, and the product portfolio covers a wide range of cranes for many types of vessels. In 1993, the former Hägglund’s company became part of MacGregor Group, a market leader in shipboard cargo care products. Besides cranes, MacGregor Group’s product range includes RoRo equipment, hatch covers, shipboards elevators, galleys, cargo securing systems and refrigerated cargo handling systems. MacGregor Group has an aim of being an active global partner to ship owners and shipbuilders for both sales and after-sales services. To meet this goal, the company has an extensive service organization with service stations in more than 50 different harbors.

MGC’s main office is located in Örnsköldsvik, Sweden. Its crane manufacturing originally took place there as well, but it has been relocated to Asia due to economic conditions and proximity to market. However, design and development are still located in Sweden, together with sales, after-sales departments, management, etc. In 2002, when the study was initiated, MGC had approximately 150 employees at the main office and a turnover of EUR 72.1 million.

MGC offers only business-to-business products and services, and maintenance services is indisputably the biggest business in the after-sales sector for the company. MGC defines services as the ability to give customers the freedom to concentrate on moving cargo and maximizing profitable operations with the knowledge that their fleets’ key systems are receiving attention from a specialist. To improve the cranes’ operations and maintenance, MGC developed a micro-computer-based crane control system that enabled remote communication to portable laptops. This development was a first step towards a remote diagnostics system for the cranes.

One year after our first contact with MGC, all development projects being pursued by MacGregor Group were postponed for economic reasons. The group also sought out comprehensive planning of all development that could be coordinated between the different divisions. The remote diagnostics project initiated at MGC was thus delayed until the Group decided that remote diagnostics was a strategic project that should involve all divisions within the group. Besides MGC, the hatch-cover division had run a similar project and had already developed a first prototype, so the whole remote diagnostics project was transferred to the hatch-cover division. The aim became to develop a system that would enable monitoring of all MacGregor Group equipment and possibly other equipment as well. MacGregor Group would thereby
become the ship owners’ trusted service partner that could take responsibility for an extensive portion of the onboard equipment – even those parts provided by competitors. Once the hatch-cover division took ownership of the remote diagnostics project, MGC was no longer directly involved in the system’s development; however, the company was of course involved in issues related to monitoring of the cranes. The service technicians at MGC tested the sensors and decided what parameters and sensors to use, and they were also involved in setting alarm levels and other analytical issues. In 2004 and 2008, we conducted small follow-up studies. The remote diagnostics system had by then been developed, but in 2008, only the hatch-cover division and MGC had been included; the involvement of the other divisions had been delayed.

The developed remote diagnostics system includes functionality to track a vessel as it travels all over the world. This is enabled by a GPS, and data are transferred via a GSM modem to a server located on the hatch-covers. A further development is the ability to transfer data via satellite. All MGC employees have access to the collected information via the company’s intranet. The tracking tool is viewed as valuable in planning on-board maintenance, and it also shows the conditions in which the equipment is operating – e.g., it can indicate if the equipment is operating in tough conditions, such as arctic or tropical environments. The system also tracks operations and running times of the equipment. Approximately 25 parameters of the cranes are monitored, such as feed pressure, oil temperature, speed, luffing, gear, temperature, etc. Alarm and error lists indicate problems that have occurred or instances when a parameter has exceeded an alarm level. The system also estimates each piece of equipment’s running time and next service occasion.

In addition to the new system, MacGregor Group also developed a new service concept, ‘we deliver uptime’, including the remote diagnostics system. After-sale services were grouped into four levels of onboard care: basic, enhanced, special and total onboard care. The remote diagnostic system is included at the highest level, where MacGregor manages all equipment maintenance in a transparent mode in cooperation with the ship crew. Our follow-up study showed that the total onboard care level of service had raised extensive interest among customers, but in 2008 there were no written contracts. One reason for this was the guarantees that delayed the need for these services. The company, however, still views the new system and the new services as strategic and believes that the market will grow within a couple of years. Until then, the company is testing the system and improving the analysis of the collected data.
4.3.2 Case 2
Case 2 was initiated in September 2002 when we first came in contact with PowerDrive (fictitious name) at a meeting at its main office. In the meeting, PowerDrive presented its remote diagnostics service and vision of combining its service and manufactured equipment into a solution offering (for further details, see paper 2). We decided to initiate a study including customers to gain a better understanding of implementations of remote diagnostics services from both a provider and a customer perspective. In all, this case study involved three organizations, one service provider (PowerDrive) and two of its customers—Alpha and Beta (fictitious names). The project ended in November 2003, and the results were presented to PowerDrive in March 2004.

PowerDrive
PowerDrive began business as a hydraulic motor manufacturer in the 1960s. Over time, the company has developed its product range and now offers complete industrial drive solutions. The drive solutions are used in a wide range of industries, such as mining, offshore drilling, rubber, plastics, pulp and paper. Its customers are located all over the world, and the company has approximately 50 sales and service offices in more than 20 countries. The company has around 700 employees, and the main office and production are concentrated in the same location. Its revenue has steadily grown and was approximately MSEK 1,175 in 2008. New sales account for around half of total sales, after-market services for just over one third and component sales for the remainder. The company’s service concept includes service contracts, system diagnostic checks, preventive maintenance and, of course, emergency repairs. A majority of the services offered by PowerDrive involve fieldwork, where the service technician visits the customer. This is an expensive and sometimes inefficient way of performing service, and the after-market executives at PowerDrive have been looking for a way to improve their business processes.

The development of the remote diagnostics system started in 1999 as an innovative means of improving the maintenance processes and offering new kinds of services. The aim was to get early warnings and alarms when problems occurred and to be able to provide real-time monitoring of their hydraulic drive system. By 2002, the company had developed the remote diagnostics system, which enabled data collection from the drive system. The system uses sensors installed in the hydraulic motor to collect data about its performance and condition, and these data are sent to a server located at PowerDrive for analysis. With the
system in place, the company wished to improve maintenance by servicing equipment when a failure is deemed to be imminent rather than when services are scheduled, regardless of the equipment’s actual condition. The remote diagnostics system was incorporated into a remote diagnostics service offer where PowerDrive inspects and makes assessments of the drive system’s condition.

**Alpha**

Alpha is a mining industry company established in 1890. The company is one of the world’s leading producers of upgraded iron ore products for the steel industry and a growing supplier of industrial minerals products to other sectors. In 2009, Alpha had approximately 3,700 employees working in the company’s iron ore mines, processing plants, ore harbors and sales offices. Alpha has a yearly turnover of approximately 16 billion SEK and a production of over 20 million t/a.

To increase its productivity, Alpha initiated a project in 2002 focused on reducing downtime and unplanned work stoppages without major investments. The aim was to achieve this goal by developing new maintenance routines and processes within the company. The project involved changes in work routines for the operators as well as new ways of working with external partners. As part of this project, Alpha decided to engage in more preventive maintenance, more specifically condition-based monitoring. Alpha was one of the first customers to implement PowerDrive’s remote diagnostics system. Alpha saw a great strategic value in remote diagnostics systems and decided to initiate a remote diagnostics project, which included the founding of a new company – Monitoring Control Center (MCC). We found this initiative interesting, and MCC’s focus on remote diagnostics services fit well with my research interests; consequently, we decided to include MCC in the research process and sought them out for a separate case study. This case study is presented in section 4.3.3.

**Beta**

Beta Group is one of Europe’s leading producers of paperboard and paper. The group has an extensive production system with units in many different European countries. This study included one of the company’s units located in Sweden. This unit is referred to as Beta. Beta was established in 1919 and produces high-quality uncoated and coated fine paper and bleached market pulp. In 2008, the company had approximately 1,000 employees and produced 435,000 t/a uncoated paper, 260,000 t/a coated paper and 700,000 t/a bleached craft pulp.
Beta has significant experience with preventive maintenance in its plant. In the beginning of the 1980s, the company realized the potential of including preventive and organized maintenance walk-rounds in the plant, which had the goal of detecting critical changes in the equipment. In 2003, the company had 12 employees working with condition-based monitoring and 14 employees who worked on maintaining the equipment at scheduled intervals. The preventive maintenance group is thereby quite large, demonstrating the company’s commitment in this area. The preventive maintenance work has over time proven to be profitable as unplanned breakdowns have decreased.

Together with my fellow researcher, I first came in contact with Beta in November 2003. PowerDrive is a supplier of hydraulic drive systems in Beta’s plant, and Beta was for a while a customer of PowerDrive’s remote diagnostics service. The company was therefore chosen as one of the customer representatives in the case study.

4.3.3 Case 3
As noted, we came in contact with Alpha during the second case study and decided conduct a separate case study with their spinoff, MCC. This latter case study was initiated in April 2004. MCC is a provider of remote diagnostics services, and in 2004, we conducted a number of interviews to gain an initial understanding of MCC and its remote diagnostics services. In 2006, an in-depth study was conducted to explore the service from both a supplier and a customer perspective, where Alpha represented the customer side.

Monitoring Control Center
MCC was established in 2003 and is a joint venture between Alpha, SKF and Sandvik. The company presents itself as a global competence center in maintenance development and condition-based monitoring with a focus mainly on the mining, minerals processing and cement industries. The company’s business concept is to provide advanced condition-based monitoring of machinery and equipment all over the world. It offers a broad range of services, from development of complete maintenance solutions and concepts for remote diagnostics to advanced condition-based monitoring using such methods as vibration measurement and thermography. The remote diagnostics service includes collection and analysis of data and communication of analysis results, partly via hardcopy reports and partly via personal contact with the individual responsible for maintenance at the plant in question. Moreover, the
company assists customers in decisions related to the results of the diagnostics.

Initially, MCC had 15 employees, but the company had grown to approximately 20 employees by 2008. Its turnover also grew from just over EUR 1 million to 1.5 million in 2008. MCC has its main office in Kiruna, Sweden, and two additional minor offices in northern Sweden for service engineers. The company was established on Alpha’s initiative, with the objective to monitor and diagnose relevant equipment in its plants. The company mainly uses technical solutions from SKF but also actively take part in development projects with other companies when needed. To develop its own analysis competence, MCC uses @ptitude, a software package where different companies can share diagnostic results and experiences with equipment in different settings.

Together with my fellow researcher, I first came in contact with MCC in April 2004, when a number of interviews were conducted to gain an initial understanding of the company. In the beginning of 2006, we conducted a larger number of interviews on both MCC and Alpha.

*Alpha*

To improve its production, Alpha decided to complete a comprehensive examination of all equipment and make investments in remote diagnostics. The company wished to work with a reliable partner that could help it manage this work and turned to SKF, a large supplier of bearings that are used in industrial equipment. Alpha also decided to organize the remote diagnostics externally as the company thought that an internal division would not be able to focus solely on condition-based monitoring and would not be able to gain experience from other organizations. As part of the cooperation with SKF, the company MCC was initiated, and Alpha became its first customer. Alpha did, however, continue with the remote diagnostics service conducted by PowerDrive.

The maintenance project initiated by Alpha was perceived as successful, and remote diagnostics were viewed as a small but decisive part of this project, which resulted in an increase in production from 20 to 23 billion tons per year of prime iron ore without any major investments.
5.1 Case study

Case studies can be conducted with a positivist, interpretive or critical stance (Klein & Myers, 1999). Although the philosophical assumptions differ between these approaches, there are many also points of agreement between them. Yin (2003, p. 13) defines case studies as “an empirical inquiry that (1) investigates a contemporary phenomenon within its real-life context, especially when (2) the boundaries between phenomenon and context are not clearly evident”. The case study method is well suited for my thesis work as it is a preferred research strategy to answer questions about contemporary phenomena over which the researcher has little or no control (Yin, 2003). This view of case studies is shared by the interpretive and positivist research approaches (Walsham, 1995b).

For this thesis, three different case studies were conducted. The first was a single case study, while the other two were embedded case studies. Embedded case studies involve multiple units of analysis within the same context (Yin, 2003). The two embedded case studies involved the service provider as well as customers as units of analysis.

The different organizations in the case studies were selected for several reasons. First, all were involved with remote diagnostics services for maintenance either as a provider or as a customer. Second, the organizations represented both remote and local work settings, enabling
the study of both ends of service production. The remote work setting is represented by service providers’ offering maintenance services and operating remote diagnostics systems. Their customers represent local work settings. Other criteria for selecting the organizations were their willingness to cooperate, the availability of multiple sources of data and the possibility of purposeful sampling (Peppard, 2001; Yin, 2003).

The case study method has been criticized due to the difficulty of acquiring similar data from different cases and the lack of control over different variables, which lead to weak grounds for generalization (Galliers, 1992). However, while these principles for generalization are appropriate for a positivistic approach to case studies, interpretive research is grounded in another philosophical base with different principles and goals (Klein & Myers, 1999; Walsham, 1993).

5.2 Philosophy
This thesis is grounded in a qualitative research tradition using an interpretive approach to investigate the role of digitalized equipment in boundary-spanning practices as a contribution to the design and implementation of IT-enabled services.

The interpretive perspective posits that our knowledge of reality is socially constructed by human actors (Walsham, 1993). Meaning is created when people interact with the world and is embedded in socially constructed representations such as language, consciousness, shared meanings and artifacts (Klein & Myers, 1999). The interpretive research approach is widely adopted in informatics research (e.g. Andersson, 2007; Henfridsson, 1999; H. Holmström, 2004; e.g. Nordström, 2003; Nyberg, 2008; Rolland, 2003; Selander, 2008; Stolterman, 1991; Åkesson, 2009) and is accepted as one of the mainstream research approaches within the IS research field (Markus, 1997). Interpretive research puts special emphasis on a phenomenon’s context (Patton, 2002), and according to Walsham (1993, pp. 4-5), the interpretive approach in IS research is “aimed at producing an understanding of the context of the information system, and the process whereby the information system influences and is influenced by the context”. This assumes that the technology and its organizational context unfold in an ongoing mutual shaping process, and a number of studies (e.g. Markus & Robey, 1988; Orlikowski, 1992; Robey & Azovedo, 1994) recommend interpretive approaches for understanding the emergent processes of organizational changes enabled by IT. This resonates well with this study, as remote diagnostics systems are an emerging phenomenon in which both the technology and its usage are still developing.
The interpretive stance draws upon a hermeneutic approach to research, which suggests that all human understanding is achieved by iterating between the meanings of the parts and the whole that they form (Patton, 2002). According to Klein and Myers (1999), this meta-principle encompasses the whole process of interpretation and is fundamental for conducting and evaluating interpretive research. My research process entailed multiple iterations between dissecting the parts of the remote diagnostics services and seeking to build them up as a whole. For instance, iterating between individuals’ perceptions of being monitored and organizational ethics is an example of such iteration.

While the emphasis on context puts the focus on the object of study, interpretive approaches also strongly emphasize the researchers as they play a crucial role in the research process. From an interpretive viewpoint, completely value-free data cannot be obtained because the research process itself relies on the researcher’s preconceptions (Klein & Myers, 1999). Moreover, through the interactions between the researchers and the subjects, researchers’ initial preconceptions are changed (Walsham, 1995a). This challenges interpretive researchers to be reflexive and to consider their role in the research process. In section 5.5, I reflect upon my own role as a researcher and assess the research process.

5.3 Data collection and analysis
In all, the research reported on in this thesis reflects a process over a period of time during which I have sought to explore the research phenomenon as outlined in the introduction. The research process was carried out over seven years, with breaks for two years maternity leave. Throughout this period, my understanding of remote diagnostics services in industrial organizations has developed, and the results of the initial studies influenced the direction of the later ones. Next, the different data collection and analysis methods used in this thesis are presented. For more details on data collection and analysis, I refer the reader to the individual papers.

Interviews were used as the main data-gathering technique. In all, 60 interviews were conducted with 48 respondents (see table 2 for further details). The respondents represented the service provider as well as the customer site. Key informants in each organization played an important role in the identification of possible respondents. The interviews were semi-structured with open-ended questions and lasted between one hour and two hours. Fifty-five of them were tape-recorded and transcribed. The interviews were conducted together with a fellow researcher, and 56
of them were conducted on site. We had a number of issues with the related questions that guided the semi-structured interviews, but we were open to pursuing follow-up questions and issues raised by the respondents (see Appendix 1 for examples of interview guides). In all cases, a report summarizing the study was given to the respondents. This helped to improve the quality of the data collection as misinterpretations could be avoided. All interview transcriptions were read by both researchers, and the reports were co-written to ensure the adequacy of the material.

<table>
<thead>
<tr>
<th>Organization</th>
<th>No of respondents</th>
<th>No of respondents interviewed two/three/four times</th>
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<tbody>
<tr>
<td>MGC</td>
<td>6</td>
<td>0/2/1</td>
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<tr>
<td>PowerDrive</td>
<td>4</td>
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<tr>
<td>Alpha</td>
<td>25</td>
<td>3/0/0</td>
</tr>
<tr>
<td>Beta</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>MCC</td>
<td>7</td>
<td>0/1/0</td>
</tr>
<tr>
<td><strong>Total number of respondents</strong></td>
<td><strong>48</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Total number of interviews</strong></td>
<td><strong>60</strong></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Overview of the interviews

*Document reviews* were also used for analytical purposes. We gained access to internal as well as external material, such as business plans, notes from meetings, consultancy reports, press releases, customer magazines and employee newsletters. On a general level, the material was used to increase our understanding of each organization and its businesses, both at the present time and on a historical basis. Moreover, we could also contrast this material with the information given in the interviews and use it to highlight important issues.

*Observations* were used to gain an understanding of activities and artifacts when we were on site. The observations were mainly linked to two goals: (1) gaining an increased understanding of the maintenance processes, business and industry through plant visits and (2) gaining increased knowledge about the organizations’ culture and developments through presence at meetings and informal socializing. The plant visits were an important tool for concretizing our understanding of the industrial maintenance process, such as the difficulties of inspecting
certain equipment physically. We kept notes of our observations and thoughts, and they were later used when analyzing the gathered material. Sometimes the observations raised new ideas about what to study and whom to interview.

Taken together, these data collection methods were used to gather rich data from the studied organizations. The interview materials and field observations constitute the major corpus of the empirical database.

Figure 3 presents the major empirical base of each paper. In each paper, the collected data were analyzed using theory-guided themes and coding to interpret meanings. Different themes are applied in data analysis in each specific paper. Overall, the coding process of each paper was initiated by a first reading of the data material, and the material was grouped based on the respondent’s position, for example, remote or local worker. Next, the coding process was guided by themes informed by the literature. The data material was sorted into relevant categories. In papers 4 and 5, this process involved cross-reading between the different cases. In this coding process, new categories sometimes also emerged from the data. The new category was then incorporated, and the previous coding was reexamined. Finally, the data in each category were analyzed separately to identify key terms and examine similarities and differences in wordings. To ensure consistency, all coding and interpretations were done in an iterative process, and in papers 1, 2 and 5, at least two researchers were involved in the coding process. In unclear cases, respondents were consulted to ensure the correct interpretation of the data.
The conclusions drawn from the analysis in each paper were input to the analysis of digitalized industrial equipment and boundary-spanning practices as a whole. This analysis was conducted on the basis of concepts from the literature on IT-enabled services, ubiquitous computing and boundary spanning. The contributions of each paper were not designed to be sequential with each one contributing a distinct input to the next; rather, they are different studies that complement each other by analyzing different aspects of remote diagnostics systems and boundary-spanning practices. The aim of this approach was to expand the scope of research and broaden our understanding of the phenomenon under study.

A summary of the five research papers is presented in section six. Table 3 clarifies my own contributions to data collection and analysis in each paper.
<table>
<thead>
<tr>
<th>Papers</th>
<th>My contribution</th>
</tr>
</thead>
</table>

| Table 3. Authors’ contributions to each paper |

By combining the contributions from each research paper addressing different aspects and reflecting on the contribution as a whole, a meta-level analysis was conducted to determine how remote diagnostics systems affect boundary-spanning practices in IT-enabled service arrangements. The whole research process has been iterative, with recurrent analysis and intervention phases. The meta-level analysis has also been an iterative process between the findings in each paper and the whole – this cover paper. The theoretical basis for the meta-level interpretation has evolved over time in response to the empirical findings and studies of the existing literature on ubiquitous computing environments, boundary spanning and IT-enabled services. The main contribution of the cover paper is presented in section seven.
5.4 Related research papers
The published research papers included in the thesis comprise the final versions of papers that have been developed over a longer period of time. Earlier versions of these and related papers have been published as academic conference papers and book sections as well as a peer-reviewed journal article. These publications have constituted an important initial step in my research, and they also reflect how my research has progressed over time. The relevant papers are listed below:


5.5 Assessment of the research process

The appropriate way to assess the research’s quality is closely related to the scientific paradigm employed. Therefore, the research has to be evaluated by its own paradigm’s terms (Healy & Perry, 2000). A well-established way of evaluating interpretive research is the seven principles proposed by Klein and Myers (1999), which are adopted in this thesis. Table 4 provides a summary of these principles.

<table>
<thead>
<tr>
<th>Principles for interpretive field research</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. The fundamental principle of the hermeneutic circle</strong></td>
</tr>
<tr>
<td>This principle suggests that all human understanding is achieved by iterating between considering interdependent meaning of parts and the whole that they form. This principle of human understanding is fundamental to all other principles.</td>
</tr>
<tr>
<td><strong>2. The principle of contextualization</strong></td>
</tr>
<tr>
<td>Requires critical reflection of the social and historical background of the research setting, so that the intended audience can see how the current situation under investigation emerged.</td>
</tr>
<tr>
<td><strong>3. The principle of interaction between the researchers and the subjects</strong></td>
</tr>
<tr>
<td>Requires critical reflection on how the research materials, or data, were socially constructed through the interaction between the researchers and participants.</td>
</tr>
<tr>
<td><strong>4. The principle of abstraction and generalization</strong></td>
</tr>
<tr>
<td>Requires relating the idiosyncratic details revealed by the data interpretation through the application of principles one and two to theoretical, general concepts that describe the nature of human understanding and social action.</td>
</tr>
<tr>
<td><strong>5. The principle of dialogical reasoning</strong></td>
</tr>
<tr>
<td>Requires sensitivity to possible contradictions between the theoretical preconceptions guiding the research design and actual findings (“the story which the data tell”) with subsequent cycles of revision.</td>
</tr>
<tr>
<td><strong>6. The principle of multiple interpretations</strong></td>
</tr>
<tr>
<td>Requires sensitivity to possible differences among the participants as are typically expressed in multiple narratives or stories of the same sequence of events under study. Similar to multiple witness accounts even if all tell it as they saw it.</td>
</tr>
<tr>
<td><strong>7. The principle of suspicion</strong></td>
</tr>
<tr>
<td>Requires sensitivity to possible “biases” and systematic “distortions” in the narratives collected from the participants.</td>
</tr>
</tbody>
</table>

*Table 4. Summary of principles for interpretive field research (Klein & Myers, 1999, p. 72)*
**Principle 1** forms the basic principle for interpretive research. It suggests that human understanding is achieved from iterating between a whole phenomenon and its parts. The research process in this thesis has been an iterative process between parts, such as empirical details of remote diagnostics services, and wholes, such as the literature on boundary spanning. Writing the thesis as a collection of papers is also a process of going back and forth between the parts, namely the articles, and the whole constituted by the cover paper. The papers reflect my interpretation of the technology. For instance, during the first study, reported on in paper 1, the main goal was to explore the business aspect of the remote diagnostics system. As we reflected upon the results of the first study, we saw how this technology changed more than just businesses. For instance, we saw how it created novel forms of human-technology relationships and changed the foundations of everyday work practices. This evolved interest influenced the second and third case studies, in which we actively sought to involve customers to further understand the implications of this technology.

**Principle 2** accounts for the context of the research setting as this is an important issue shaping IT use. Section four presents the industrial setting and the remote diagnostics system and its use in maintenance services. The research papers also provide information on the industrial setting and the technology. These descriptions aim to provide the reader with the background needed to understand the current and emergent use of remote diagnostics systems in industrial maintenance processes. Accounting for the social and historical background of the research setting also means considering it in the interpretations of the data. For instance, in paper 2, we account for the historical mass-production orientation at PowerDrive when interpreting the supply of the remote diagnostics service.

**Principle 3** calls attention to the researcher and her interactions with the participants. The research process for this thesis was designed so that two researchers conducted the data collection. Although we had different overarching research questions, this design gave us the opportunity to continuously discuss and reflect upon our presence at the research site, the data collection and our interpretations. Industrial maintenance work is a context dominated by men; we only interviewed two females for the studies presented here. As both researchers conducting the interviews are female, we often constituted an oddity when entering the plants. However, we think this had a positive effect on our research. We were not afraid of asking the ‘wrong questions’; we admitted our poor initial understanding of the context; and both of us
felt that the respondents were open-minded and really strived to explain their perspective of the context in general and of the remote diagnostics service in particular. Many respondents also admitted their joy in our interest in their daily work, and they found it stimulating to be able to reflect upon their work. However, it should also be mentioned that, of course, we met with suspicious respondents who were afraid that their opinions would be exposed to management. To overcome this, we clearly stated in all interviews that we are objective in the sense that we do not represent management and all respondents will be anonymous and will be able to comment on the case reports before they are disseminated. All respondents were satisfied with this arrangement.

As our initial understanding of the research phenomenon was sparse, the initial study at MGC had an explorative nature to help us understand the object of study. Over time, our understanding of the phenomenon developed, and during subsequent studies we often saw similarities between the cases. As we involved providers as well as customers in the study, we were able to view the remote diagnostics service from two viewpoints as opposed to being limited to one perspective.

Principle 4 regards abstraction and generalization and highlights the importance of transparency, enabling readers to follow how the theoretical insights evolved from the data. Depending on the specific focus in each research paper, various theories have been applied in the interpretation of the data. We have carefully related the details of each study to the theoretical abstractions in the analysis process. To make this process open to the reader, we have, for instance, used quotations from interviews and documents to link the data to the theoretical abstractions and generalizations. In the meta-level analysis of digitalized industrial equipment and boundary-spanning practices conducted in this cover paper, the interpretations are based on the individual papers to allow the reader to follow the logical reasoning behind the conceptualizations. The wider implications of this study can be categorized according to Walsham’s (1995b) four types of generalizations deriving from interpretive case studies: the development of concepts, the generation of theory, the drawing of specific implications and the contribution of rich insight.

The first type of generalization refers to the development of new concepts that can be used to describe a phenomenon. For instance, paper 4 contributes to the development of concepts where ‘the embedded panopticon’ is introduced as a lens to understand the surveillance capability in remote diagnostics systems. Second, theory generation is a type of generalization that refers to how theoretical
frameworks can be developed from case studies. For instance, paper 5 and the cover paper contribute with theory generation where theories of boundary-spanning practices are further developed. Third, drawing specific implications yields generalizations that can be valid in similar domains. Paper 2 gives examples of such implications as it shows that a historical mass-production focus can hamper an organization’s service orientation. Finally, the fourth type of generalization is the contribution of rich insight, which refers to insights that cannot easily be categorized as concepts, theories or specific implications. This thesis contributes with general insight into studies of IT in industrial settings, and more specifically, the thesis gives insight into remote diagnostics services, which is also an unexplored issue within the research field.

**Principle 5** focuses on the preconceptions guiding the research design. In section 5.2, the reader is presented with the philosophical roots and the fundamentals on which empirical data are construed, documented and organized. The researchers involved continuously discussed how the data were analyzed, and we compared and contrasted our interpretations. We have not limited the analysis to theoretical themes but also allowed new themes to emerge. In interpretive research, the researchers’ prior assumptions, beliefs, values and interests influence the research (Orlikowski & Baroudi, 1991). In the discussions with my fellow researcher, we have been alert to our beliefs and their implications for our interpretations. Thanks to my fellow researcher, the analysis and interpretations could be discussed and read by a researcher who shared the same access to the empirical data. For further discussions of our initial understanding of the research context, see principle five. Even though we had had few or no prior assumptions about the specific research context, our understanding has developed over time. In contrast to a monograph, the collection of papers gives the reader insight into how my understanding of the research context has evolved over time.

**Principle 6** accounts for multiple interpretations, which requires the researcher to seek out and document multiple viewpoints and the reasons for them. To explore the remote diagnostics service from different viewpoints, we decided to include providers and customers in the study, but we also sought to include respondents from different positions. For instance, we interviewed technicians, after-sales managers, service engineers, developers and maintenance managers. By combining the different viewpoints, we have sought to find multiple viewpoints on the technology. For instance in paper 4 the surveillance aspects of remote diagnostics services are discussed from the viewpoints of the service provider and the employees exposed to this capability.
Principle 7 regards the principle of suspicion, which says that the researcher should try to ‘read’ the social world behind the words of the respondents. This principle is the least applied in IS research as there are disagreements regarding the extent to which social research can and should be critical (Klein & Myers, 1999). Combining different viewpoints from different respondents in this research design has been a way to find conflicting results and, at least to a certain extent, to be suspicious regarding the collected data.
Chapter 6
Research Papers

This thesis is a collection of peer-reviewed papers published in international IS and service management journals. The papers have been published throughout the research process as a means for continuously ensuring the validity of the studies through review and criticism by the academic community. The publishing process has provided me with opportunities to engage with other academics in discussions around both empirical and theoretical concerns and to receive important comments and feedback from reviewers, co-authors and editors.

Each individual paper in this thesis contributes to investigating the role of digitalized equipment in boundary-spanning practices as a contribution to the design and implementation of IT-enabled services. Different aspects of this theme are elaborated upon in the different papers, and taken together, the intention is that they will provide a rich understanding of the particulars of this study.

This section will summarize each paper and relate the individual contributions of each to the overall contribution of this thesis. The papers are introduced in order of appearance.
6.1 Summary of Paper 1

**Paper 1**
Building on data from the first case study, this paper explores the potential use of remote diagnostics systems for the manufacturing industry by exploring how they can enable new businesses. Using Porter’s (1985) notion of a value system, we pay specific attention to impacts on the value creation process consisting of relationships, roles and architecture and to the value proposal consisting of a business offer and customer value. In the paper, we learn about MacGregor Crane as an innovative manufacturing company with ambitious visions of developing new after-sales related services to create new value for itself as well as its customers.

By analyzing two different technical solutions, the paper shows how remote diagnostics systems can allow manufacturers to become remote service providers while customers can either become co-creators of value or passive receivers of created value. When deploying a remote diagnostics system at a customer’s site, data connections allow both the collection and transfer of data that can be valuable to the customer as well as the supplier. The new data flow can potentially solve many problems related to the manufacturer’s processes of attaining knowledge across external organizational boundaries as the information is then no longer carried by different individuals or connected to certain occasions. Instead, data are transferred by the system with no notice taken of organizational boundaries or settings, and they remain stable over time. Moreover, possibilities for the manufacturing industry to design new kinds of business offers based on remote presence are also created. With real-time monitoring, manufacturers will be able to monitor the equipment wherever it is in the world.

Although there seem to be many possibilities, this paper also calls for attention to the potential risks associated with remote diagnostics systems. The use of remote diagnostics systems for the delivery of remote services can depersonalize the service experience as it can take place unobtrusively. Moreover, there will always be errors that are beyond the scope of the installed sensors. With the use of the system, the manufacturer will also have access to data on how the equipment is used. Improper use and neglected maintenance can thereby be traced by the system, which can be sensitive issues to manage in the customer relationship.
6.2 Summary of Paper 2

**Paper 2** This paper is co-authored with Saara Brax from Helsinki University of Technology. We deploy a comparative case study of two manufacturers using a remote diagnostics system for leveraging a remote diagnostics service. The two case studies were conducted separately, and my empirical portion of the paper builds on data collected in the second case study. The case study includes data from the manufacturer as well as its customers. In the paper we learn about PowerDrive, a manufacturing company with visions of developing innovative business offers with the use of a remote diagnostics system. The paper describes the company’s vision of turning into a solution provider where products and services are combined into a long-term business offer. The remote diagnostics service is an essential part of this vision as it enables manufacturers to diagnose equipment at a distance.

This paper provides a snapshot of the real-life situation of manufacturing firms trying to resolve the complexities encountered in designing and implementing a remote diagnostics service. Although the new service has the potential to help in detecting failures, planning maintenance and backup field service visits and troubleshooting, the manufacturer struggled to promote it. However, the manufacturer was satisfied with the remote diagnostics system as such as its product development division quickly recognized the potential to generate field knowledge of the equipment in use.

This paper identifies mass production-oriented thinking aimed at developing off-the-shelf products as a hindrance in remote diagnostics service design and implementation. The value-capturing logic needs to emphasize the continuous joint production instead of the point of sale. On the manufacturer side, the remote diagnostics system was often simply delivered and installed instead of being used as a resource for collaborative purposes. The manufacturer neglected to work closely with workers at the customer sites; instead, representatives of the manufacturer tended to rely on the technology as the collaborative interaction channel. Customers were then left with uncertainties and even dissatisfaction. This paper thus illustrates the need to eliminate the
mass orientation focus in remote diagnostics service situations in favor of a more customer-oriented focus.

6.3 Summary of Paper 3

**Paper 3** Building on data collected in the third case study, this paper explores the implications of embedded technology for the provider-customer relationship in remote diagnostics services. As noted in paper 2, remote diagnostics services build upon a close and long-term provider-customer relationship, which can be characterized as an embedded relationship. These relationships are a deepened form of service relationships traditionally based on close cooperation between the service provider and the customer. Remote diagnostics services form a deepened and long-term service relationship with the need for close cooperation with workers at the customer firm as they make decisions about upcoming repairs and maintenance activities. However, with its embedded sensors, the remote diagnostics system can automatically collect and transfer information about the equipment’s condition, and the options for direct face-to-face collaboration between the service provider and the customer are reduced. This collaboration is, however, still important, as the local staff can complement the remotely collected information with information about environmental issues that the sensors cannot detect.

Drawing on Uzzi’s (1997) framework on embedded relationships, the implications of IT for embedded relationships in IT-enabled services are analyzed. The paper draws attention to the role of social efforts by the humans involved in the service. Social efforts can maintain a close collaboration at a distance. As the remote diagnostics service is leveraged by embedded sensors and provides an information flow that can operate unobtrusively at the customer site, uncertainties arise within the customer organization regarding the technology and the service delivery. Relevant issues are, for instance, whether or not the monitoring is actually taking place and why the manufacturer can predict a certain issue but not another. Although the remote diagnostics system enables a continuous information flow and monitoring of the equipment, the customer and manufacturer need to maintain or even intensify their interactions; otherwise, relevant information may be neglected and/or the customer may feel overlooked. Besides developing trust in the other
party in the business service relationship, trust in the technology needs to be developed. Trust in the technology helps to create realistic expectations regarding the remote diagnostics service, as humans in the monitored setting come to understand its possibilities and limitations.

6.4 Summary of Paper 4

**Paper 4** This paper builds on an analysis of data collected from all case studies to explore the ethical issues of surveillance in remote diagnostics systems. While the primary aim of a remote diagnostics system is to monitor the equipment in order to prevent breakdowns, the system is also capable of monitoring the operating procedures and thus also the operators. For instance, it is possible to monitor the working time of certain pieces of equipment and thereby the lengths of operators’ breaks.

The paper adopts both a customer and a supplier perspective, and the analysis draws upon the panopticon framework (Foucault, 1979). With embedded sensors, surveillance can potentially be everywhere, performed by any actor for unknown purposes. Digitalized equipment with embedded technologies thus contradicts the fundamentals of privacy protection as the extent and the purpose of the data collection are difficult to define, and people can hardly be informed of what is being collected due to both practical reasons and incompatibility with the very goal of pervasive penetration into the everyday environment.

The paper discusses how visibility and invisibility are of decisive importance concerning whether or not people can examine ethical dilemmas in computer use as visibility seems to be what triggers employees’ feelings of being monitored or not. Despite their monitoring possibilities, remote diagnostics systems do not seem to evoke such feelings. By embedding technology and thereby also monitoring into physical things, both the technology and the cues of surveillance become concealed, both literally and virtually, for the customer. To the remote diagnostics customer, the direct reminders of surveillance are thus embedded in the technology, creating an embedded panopticon. As the customer cannot examine possible ethical dilemmas, the responsibility for doing so remains with the suppliers, who must pick a strategy for how to handle ethical questions. The ethical dimension may thus become a critical issue to manage in the service relationship.
6.5 Summary of Paper 5

**Paper 5** In building on data from the second and third case studies, this paper explores the impact of remote diagnostics systems on boundaries and boundary-spanning practices. Building on the boundary-spanning literature, the paper calls attention to the impacts of material features afforded by IT systems as they have a significant impact on the form and content of boundary-spanning practices.

In the paper, we observe that material features of the remote diagnostics system lead organizations to change their boundary-spanning practices in contradictory ways. On one hand, the system has helped to reinforce existing boundaries. On the other hand, it has crossed or cut down others or created new ones. These processes have re-shaped the boundaries and practices in the daily work of maintenance technicians.

Moreover, the remote diagnostics system generates changes in the nature of boundary-spanning practices. With the use of remote diagnostics systems, boundary-spanning practices are no longer a mere social activity. The technology causes profound changes that go beyond provisioning of additional means for the remote technicians to span boundaries. First, the main object of work is changing for the remote technicians as sensor information becomes their work material. Analysis competencies become more crucial than hands-on competencies like listening to the sound of the equipment. Second, the remote diagnostics system enables a new kind of data transfer, and remote centers now emerge where data can be collected from local and global contexts. Knowledge can now be extracted from data collected from many settings without the need for physical travel. Moreover, data collection is now stable, systematic and disciplined instead of being dependent upon the initiative and skill of each local technician. Finally, the remote diagnostics system also changes how the boundaries are defined. Those who can define access to data gain new boundary-spanning capabilities as they assimilate new types of knowledge. However, those who are excluded experience reinforced boundaries. Taken together, the data flow and computer environment thus change the foundations upon which boundaries of knowing and acting are drawn.
Chapter 7
Discussion

The core of the IS research discipline has been debated ever since the field was born (Weber, 2003). One recent issue in this debate is the call for IS researchers to focus their attention on the IT artifact (Benbasat & Zmud, 2003; Monteiro & Hanseth, 1996; Orlikowski & Iacono, 2001). This call seems to spring from the need to take the praxis at the IS field’s center more seriously, e.g., the ways in which the specific characteristics of IT have profound effects on their surroundings. The intent behind this increased focus on the IT artifact is laudable as it is aimed at consolidating the work of the IS field and reinforcing the praxis at its center (Lyytinen & King, 2004). However, to avoid “the tendency to tilt” (Leonardi & Barley, 2008) and favor only the social or the material factors, research needs to pay attention to the intersection of the technology and its context, e.g., to focus carefully on the IT artifact that is created and has materialized in practice and its effects (Lyytinen & King, 2004). In this thesis, the remote diagnostics service constitutes the context of application for the remote diagnostics system. The thesis has explored how these novel forms of services and boundary-spanning practices are leveraged by digitized equipment connected with a remote diagnostics system.

In a world with digitalized equipment, physical artifacts are provided with properties that differentiate them from their non-digital counterparts. Equipment is not merely evolving in terms of novel
features; it is as much about changes in people’s interpretations of what the product is and what it can be used for (Bijker, 1995). Visually, the equipment may look just like before, but the embedded digital components provide it with new materiality properties.

In contrast to the mobile technologies that have gained so much attention in ubiquitous IS research, this thesis contributes insights on embedded (invisible) technology. This technology is significantly different from mobile technologies, which underscores the importance of paying detailed attention to the specific technology being studied (Orlikowski & Iacono, 2001).

This thesis aims at investigating the role of digitalized equipment in boundary-spanning practices as a contribution to the design and implementation of IT-enabled services. To this end, I have analyzed how the implementation of remote diagnostics systems affects boundary-spanning practices in IT-enabled service arrangements.

The investigation of IT’s effect on boundary-spanning practices started with the basic premise that IT is a critical enabler and constrainer of boundary-spanning practices (Clemons & Row, 1993; Hayes, 2001; Levina & Vaast, 2006). While the issue of how IT affects social practices has been a long-standing challenge in IS research (Leonardi & Barley, 2008; Monteiro & Hanseth, 1996), little attention has been paid to how the specific characteristics of IT affect boundary-spanning practices. In the boundary-spanning literature, IT is merely treated as a mediator facilitating the human boundary-spanners, and its specific characteristics are often black-boxed.

7.1 Boundary spanning as multicontextual practice
This thesis shows how remote diagnostics systems enable stable and continuous monitoring of industrial equipment on the 24/7 principle. Global knowledge centers can be created where the remote diagnostics systems provide deep insight into the condition of the monitored equipment. These insights are enabled by the equipment’s new properties of sensibility and communicability, which are new materiality properties differentiating digitalized equipment from its non-digital counterparts (Yoo, 2010).

Moreover, the thesis shows how the remote diagnostics system helps to span external as well as internal boundaries of the organization (noted in papers 1, 2 and 5). However, while the remote diagnostics system holds the potential for additional boundary-spanning capabilities, it may also create new and reinforced boundaries (noted in paper 5). As the diagnostics of the equipment can be conducted at a distance, a new
boundary arises between the service provider and the monitored equipment (noted in paper 5). Although certain boundaries are reinforced, the service providers and the customer benefit from the new boundary-spanning capability.

As noted earlier, Lindgren et al. (2008) distinguish two basic perspectives on boundary-spanning practices: a work practice perspective, which recognizes boundary spanning as essential to learning, and an innovation perspective recognizing boundary spanning as essential for organizational renewal. These two perspectives are adopted to further understand how remote diagnostics systems affect boundary-spanning practices. Table 5 summarizes these findings from the viewpoints of the service provider and the customer.

<table>
<thead>
<tr>
<th>Organizational context</th>
<th>Organizational learning</th>
<th>Organizational innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service provider</td>
<td>Knowledge of equipment in use in multiple settings</td>
<td>New business services</td>
</tr>
<tr>
<td></td>
<td>Deepened knowledge of equipment maintenance</td>
<td>Changed maintenance recommendations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Equipment development</td>
</tr>
<tr>
<td>Customer</td>
<td>Knowledge of equipment in use</td>
<td>Outsourced maintenance services</td>
</tr>
<tr>
<td></td>
<td>Improved knowledge of maintenance</td>
<td>Changed maintenance routines</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Improved use of equipment</td>
</tr>
</tbody>
</table>

Table 5. A multicontextual perspective on boundary-spanning practices

The service providers can now engage in real-time knowledge creation regarding the equipment in use in multiple contexts (noted in papers 2 and 5). Before the use of the remote diagnostics system, separate inspections were conducted by different technicians when the equipment was not running. The system has enabled transfer of data from multiple contexts into one place, where technicians can gain an overall view of the running equipment in dispersed settings. The knowledge base for the service provider is thus expanded as it gains experience from analyzing the performance of multiple pieces of equipment. The service center can be compared to a ‘center of calculation’ (Latour, 1987). Through remote diagnostics of the equipment, the service providers also obtained deepened knowledge of the maintenance processes (noted in papers 2 and 5). They learn more regarding the appropriate time intervals for component replacements and how use cycles affect the condition of the equipment. The customers also benefit from the remote diagnostics as
they can also learn more about the equipment in use and the maintenance processes. However, as they cannot access the remote diagnostics system, they gain these insights via information shared by the service providers. From an organizational learning perspective, the remote diagnostics system makes available novel information that creates new knowledge for service providers as well as customers.

From an organizational innovation perspective, the boundary-spanning capability enables development of new after-sales related services (noted in all papers). Either a standalone remote diagnostics service is offered, or it can be incorporated into a broader service offer where the digitalized equipment can serve as a platform for total maintenance services (diagnosing and maintaining the equipment) or for services related to its performance, e.g., performance contracting (Kim, Cohen, & Netessine, 2007). The manufacturer’s deepened insights regarding maintenance can also lead to changes in recommendations regarding when the equipment should be maintained (noted in paper 5). When the service provider is the equipment manufacturer, the information gained from the system can be used directly for development of the equipment (noted in papers 2 and 5). In cases when the manufacturer and service provider are separate organizations, the manufacturer can only receive such information indirectly via the service provider.

As information can easily be collected and transferred across organizational boundaries and central service centers with knowledge from many external settings can be created, customers may also seek to reorganize their maintenance organization and outsource the diagnostics portion to focus on other processes (noted in paper 3). Based on the information gained via the remote diagnostics system, customers also change their maintenance routines and their use of the equipment (noted in papers 1, 3, 4 and 5).

As this thesis shows, information gained via the remote diagnostics system is beneficial for organizational learning as well as innovation; as novel information can be gained on the equipment in use, new services as well as new maintenance routines are developed. Organizational learning and innovation thus mutually shape each other. This perspective supports the finding of Lindgren et al. (2008) that ubiquitous computing environments allow for collection and transfer of contextual information that is useful from both a work practice and an organizational innovation perspective. However, this thesis adds the perspective of multicontextual practices, showing how information can be useful in a multitude of contexts. Service providers, equipment manufacturers and equipment
users are examples of different entities that can benefit, directly or indirectly, from information gained via the remote diagnostics system. However, in this study, the system was not designed to allow for a direct information transfer to all contexts. By directing the information flow to only one context, the service provider sought to gain a base for creating new businesses. This way of locking the information can be contrasted to vehicle services (Kuschel, 2009), where information is presented to drivers as well as car manufacturers/service providers. Additional methods to accomplish this are also to exclude the service dimension and to provide the system as a product where information is mainly transferred to the customer (Andersson & Lindgren, 2005). However, compared to a product strategy, the service strategy enables a shared view on what data are collected and for what purposes. Customers and service providers are mutually involved and seek to find and customize a solution that adds value to the customer organization.

7.2 Digital sensing as sociomaterial practice
This thesis shows that with the implementation of remote diagnostics systems, boundary spanning is no longer a mere social activity. IT has become deeply intertwined in boundary-spanning practices as the sensors installed in the monitored equipment serve as the remote technicians’ eyes and ears. Together these two—the technology and the technicians—form a boundary-spanning assemblage. This assemblage intertwines the social and material into a processing whole where the parts are mutually dependent. This view of entwinement has similarities to sociomateriality (Orlikowski & Scott, 2008), which is an emerging stream of research that equally weighs the material and the social and thus accounts for both parts. Svahn, Henfridsson and Yoo (2009) adopt sociomateriality to explore the entanglement of material and human agency in digital innovation leveraged by digitized products.

The term ‘assemblage’ is used in this thesis to capture the novel form of boundary-spanning practices resulting from the use of remote diagnostics systems. Assemblages are active (Law, 2004) and consist of symbiotic elements that co-evolve, and they do not function according to strict cause-and-effect models (Olds & Thrift, 2005). The assemblage is used in this thesis to capture the boundary-spanning process in the studied context. In this context, the assemblage is a way to capture the intertwining of human competencies with technological affordances. In the boundary-spanning assemblage, these are inseparable parts that cannot be pulled apart and function on their own. Figure 4 depicts this new perspective on boundary-spanning practices.
With digitalized equipment, technology is so deeply embedded in information collection processes that the boundary-spanning assemblage cannot operate without the technology. However, in a similar way, the analysis competencies of the technicians are so intertwined with the monitoring process that their activities create a need for the boundary-spanning assemblage. This perspective differs from that of existing research that views boundary spanning foremost as a human activity that can be supported by but is not dependent on IT (e.g. Clemons & Row, 1993; Hayes, 2001; Levina & Vaast, 2006; Yan & Lewis, 1999).

Boundary-spanning assemblages cause novel changes in existing boundary-spanning practices. Remote diagnostics systems automatically collect and analyze data at pre-defined time intervals, yielding continuous, stable and systematic information flows between the service provider and the customers’ equipment (noted in papers 1 and 5). The systems also give up-to-date information about the equipment’s condition that is transferred directly from the equipment to the service provider with no intermediaries (noted in paper 1). In addition, the system also enables a focused but expanded opportunity for data collection (noted in papers 3 and 5). Due to machine design and safety regulations, it is impossible for humans to inspect the equipment in the same way technology does. As a result, the sensors expand human sensing abilities: they can monitor things that humans cannot and work
in places humans cannot reach. However, the information flow is limited to the sensors embedded in the equipment, and no additional information can be gained via the remote diagnostics system about the equipment’s status and environment (noted in papers 1 and 5). When combined, the technicians and the technology engage in a novel form of digital sensing. Moreover, remote diagnostics systems are designed as one-way systems in which the service providers can only receive information from the system: in other words, they cannot send anything back to the equipment.

Besides the remote diagnostics system, the remote technicians act as an important part of the boundary-spanning assemblage. They can engage in social-to-social boundary spanning with the local technicians, who can provide them with additional information that the system cannot collect (noted in papers 3 and 5). Moreover, the technicians can both collect and diffuse information, but the occasions for these activities are often ad-hoc (noted in paper 5).

By implementing remote diagnostics systems into the work practices of the remote technicians, boundary spanning changes from an activity mediated by IT to an IT-intense activity. In contrast to other forms of IT applications such as email, remote diagnostics systems do not merely transmit and store information; they also have the ability to produce and transform information that can be acquired by no other means. Together, the technicians and the system can engage in knowledge creation that was not possible before. Knowledge can now be extracted from data gained from many settings without the need for physical travel (noted in paper 5). However, with the deployment of the remote diagnostics system, new competencies in data analysis are necessary (noted in paper 5). Analytical competencies have replaced the hands-on competencies that historically characterized preventive technicians’ work.

With remote diagnostics systems, maintenance practices require new ways of organizing and working. As remote diagnostics systems transform analog information into a unified digital format, previously unrelated information can now be easily manipulated and combined to create new families of representations. Recommending actions based upon interpretations of automatically collected data is a challenging task in an environment accustomed to basing actions upon physical presence and manual skills. Grudin (2001) argues that learning to work in a world of context-aware applications is one of the greatest challenges that we face today. These kinds of systems thereby do not just change work practices; “they often change the nature of the work itself” (Leonardi & Barley, 2008, p 165). In the case of boundary-spanning assemblages, this
means that changes are profound and go beyond provisioning of additional means for the technicians to span boundaries.

First, the main object of work is changing for the remote technicians as sensor information becomes their work material. Analysis competencies become more crucial than hands-on competencies like listening to the sound of the equipment. However, these hands-on competencies, or tacit knowledge (Ehn, 1988; Göranzon, 1984), are still important as sensors only collect data on limited parameters. The hands-on competencies need to be maintained among those technicians working in each plant, and these competencies should complement the remote technicians’ competencies. For the remote technicians, the ability to interpret the signals from a sensor is now just as important as competence in gaining information from local technicians. Information transfer and boundary-spanning practices no longer solely rely upon human relationships. IT constitutes a crucial element, and thus, what it means to be a preventive maintenance technician and boundary spanner has changed.

Second, boundary spanning concerns collecting and making sense of peripheral information to expand an organization’s local knowledge. Perceived changes in boundary spanning will generate changes in the organization’s knowledge management. The remote diagnostics system enables a new kind of data transfer, and ‘calculation’ centers have now emerged where data can be collected from local and global contexts. Together, the technicians and the system can engage in knowledge creation that was not possible before. Knowledge can now be pulled out from data gained from many settings without the need for physical travel. Moreover, data collection is now stable, systematic and disciplined instead of being dependent upon the local initiative and skill of each technician. A complex socio-technical organization emerges at the remote level as data from multiple external settings flow to the remote centers, where they merge and create new product and analysis knowledge.

Finally, the remote diagnostics system also changes how the boundaries are defined. Boundaries are no longer defined based merely on physical attributes like access to a local setting and personal relationships. Rather, data instrumentation, rate and quality of flow, accessibility and analytics shape the boundary setting. Those who can define access to data gain new boundary-spanning capabilities as they assimilate new types of knowledge. However, those who are excluded experience reinforced boundaries. Taken together, the data flow and
computer environment change the foundations upon which boundaries of knowing and acting are drawn.

Looking at the diverse ways in which local knowledge is collected, shared, analyzed and distributed, one could argue that the boundaries for cognitively sensing the world of industrial equipment are now significantly expanded. Due to machine design and safety regulations, it is impossible for humans to inspect the equipment in the way machines do. As a result, the sensors expand human sensing: they can monitor things that humans cannot and work in places humans cannot reach. Digital sensing is enabled, where human competencies and technological affordances are combined. Our case thus illustrates how social competencies become materially entangled, to use Woolgar’s (2002, p. 265) term. That is, human competence becomes inextricably entangled with the technology as we conceive boundary spanning as a boundary-spanning assemblage. In particular, this thesis shows how the technological and social become entangled in new forms of boundary-spanning assemblages as technology’s features in the end both enable and constrain boundary spanning. The thesis also illustrates how, on one hand, sensors expand human sensing and how, on the other hand, technicians’ competencies become pervasively entangled with the new technology. As the entanglement deepens, understanding technological features becomes more important in understanding the work process.

As the use of IT changes the premises of how boundaries are defined, the traditional view of boundary spanning as a purely social activity (Leifer & Delbecq, 1978) meant to serve as a link between the organization and its environment (Aldrich & Herker, 1977) needs to be questioned. Current research raises the pivotal issue of how IT serves as an effective mediator of increased boundary spanning (e.g. Hayes, 2001; Yan & Lewis, 1999). This analysis provides a different story: contemporary IT infrastructures evolving towards ubiquitous computing environments will stretch the role of IT beyond that of a mere mediator (Miller, 2005). Boundary spanning has turned into a complex boundary-spanning assemblage where social and technical resources are inherently intertwined. These environments can automatically collect and analyze data, and by doing so, technology expands the scope of the human senses and becomes an active part of a boundary-spanning assemblage. Boundary spanning is no longer a social activity dependent upon whom you know and what you talk about. Rather, it becomes crucial to have access to the data and knowledge of how to interpret and use it. IT thereby adds the dimensions of connectivity and competencies involved in making efficient use of digital information.
Chapter 8
Conclusions

Digitalized equipment with embedded technology raises not only novel opportunities but also novel challenges for research as well as practice. We can now design IT solutions where people close to the technology have no access to or awareness of it. We can be monitored without visual cues of the monitoring, a possibility that raises ethical issues related to IT use. The embedded technologies also extend human sensing and capture data that were previously non-existent to the human senses. Properties of communicability enable an extended globalization that is not merely about connecting people around the world: equipment can be connected as well. Digitalized equipment creates an information-intense environment where data can flow across organizational boundaries. This thesis has paid particular attention to the technology’s boundary-spanning effects.

8.1 Implications for practice

When computer components are embedded in physical artifacts, it becomes more difficult to talk about the equipment on one hand and IT on the other hand: for users, they constitute a whole. Moreover, due to its invisibility, embedded technology also challenges users’ and researchers’ capability to understand and reflect on IT. Digitalized equipment thus challenges people to develop reflexiveness and maturity of their IT use. According to Persson (1987), this maturity refers to
people’s ability to constructively question IT activities. As sensor technology and digitalized equipment are a growing part of people’s lives, this reflexiveness is not needed only in industrial settings; rather, it will be an essential ability for everyone.

In the organizational setting, managers can benefit from gaining further insight into the intertwining of IT and human competencies into a boundary-spanning assemblage. First, the organizational boundary itself may change by being reinforced or spanned. Second, in boundary-spanning assemblages, technological affordances are just as crucial as social affordances. Boundary spanning is no longer based merely upon social skills and social networking. IT-related competencies, such as analysis knowledge, are equally important, and practitioners need to engage deeply in creating and maintaining such knowledge. Third, boundary-spanning assemblages add the dimension of access: only those who can gain access to the technology can participate in the boundary spanning. Those who are excluded may not even be aware of the processes taking place. Moreover, boundary-spanning assemblages encourage an integrative view of IT and the social context in which they are designed and maintained as a whole and not as two separate entities.

In the IT-enabled service setting, both benefits and limitations of the boundary-spanning assemblage need to be considered. In order to gain additional external knowledge across boundaries, the service provider and the customer may need to engage to exchange information in many different ways. While the embedded technology provides one such resource, additional resources are needed as well. For instance, different mobile and communication technologies may be needed in addition to possibilities for face-to-face information exchange. For managers, it becomes a key organizational challenge to manage a heterogeneity of knowledge resources and IT artifacts to expand the boundary-spanning capability. In service relationships where only one party can access specific digitalized equipment, it may be a great challenge to implement such resources. Digitalization may engender feelings of mistrust and surveillance, which raises new and important issues in the service relationship.

From a business perspective, digitalized industrial equipment can serve as an enabler of a new kind of physically enabled IT services. In the long run, digitalized equipment can communicate with different service providers to provide a variety of services. Manufacturers may seek to integrate sensors during production to prepare the equipment as a platform for services. Manufacturers can choose either to provide these
services on their own or to sell access to the digitized information to external service providers.

8.2 Implications for research
Digitalized industrial equipment presents novel opportunities and challenges for organizations, users and researchers. However, the convergence of equipment and embedded technologies (Lyytinen & Yoo, 2002b) has not been widely recognized in current research (Yoo et al., 2008a). Studies of vehicle services (Kuschel, 2009) and innovation processes leveraged by digitized vehicles and road haulage systems (Andersson, 2007) are rare exceptions. This thesis extends these prior studies with a study of remote diagnostics systems in industrial organizations.

To summarize, these systems deeply influence how organizational boundaries that are drawn as ‘cross-overs’ are now less limited by constraints of time, space or the type of data shared (Jessup & Robey, 2002). These systems permit workers at remote sites to gain access to information about external dispersed equipment and production processes. They also create new boundaries between entities that were not connected before and cross previously existing boundaries with new information and knowledge. It can be speculated that IT will continue to significantly shape organizing logics that determine where and when organizational boundaries are drawn and crossed.

Ongoing and future boundary-spanning practices will increasingly be shaped by boundary-spanning assemblages where social and technical capabilities are entwined and brought together by increasingly ubiquitous IT capabilities.

While current research has called for attention to the ‘IT artifact’ in IS research, this thesis underscores the profound effects of the characteristics of the specific IT (in the form of a remote diagnostics system) on its surroundings. Moreover, in contrast to predominant ubiquitous computing research that mainly explores mobile applications, this thesis shows how the increased embeddedness of IT makes technology an invisible but always present part of everyday work practices. However, this invisibility limits users’ as well as researchers’ capacity to understand and reflect on IT. As researchers, how can we account for the role of IT when we cannot distinguish it as a separate entity? A reflection from this thesis is that the before and after comparison helped informants to reflect upon their work with digitalized equipment. Digitalized equipment thus raises novel issues for research that are not present in pure mobile applications.
Furthermore, using IT for business-to-business services raises implications for research. The service perspective entails an environment with providers, customers, information users and consumers as well as the organization of this environment. To develop or use an IT-enabled service is not merely about developing/using a technology or a system; it also includes issues about the technology’s value creation, ownership, competencies and customer relationships. IT and services should thus not be considered as separate and subsequent processes: they are deeply intertwined and mutual. For research, this means that IT cannot easily be separated from service, and we should not approach IT and services as two distinct entities.

8.3 Limitations and future research
This thesis involves a number of limitations that can be attributed to issues of the research context, the framing of the technology and the theoretical framework. First, all case studies were conducted in the industrial context, thereby limiting the empirical generalizability of the observations. This context involves specific circumstances that might not apply to other organizational settings. Second, the remote diagnostics systems that are studied are framed within a service offering. This creates a detailed but very specific framing, which limits the results. Finally, the boundary-spanning framework limits the empirical explanations and theoretical contributions by focusing the analyses on specific issues while ignoring other issues. Nonetheless, even with these limitations, this thesis offers important contributions to IS research and the boundary-spanning literature as well as implications for research and practice.

The limitations also open up directions for further research, and the findings raise new questions and ideas that merit further studies. First, because the literature is silent on embedded technologies and digitalized equipment, the field would benefit from further empirical studies of such implementations. Specifically, we need to extend our area of purview beyond the mobile technologies for personal use that have attracted so much attention in recent years. The agenda should be to capture variations in technologies, including sensor-based systems, and also to include studies of organizational use.

As IT is a critical enabler of services, this field would also benefit from further studies of IT-enabled services. We need to better understand the implications of IT in services; therefore, studies are needed that, for instance, focus on how IT affects the provider-customer relationship, what the globalization of expertise means for service delivery, what new
skills and knowledge are required, and what new digital business processes IT enables. The IS literature has been sparse on studies of IT-enabled services, but I think this is a growing research field, and the call for papers to *MIS Quarterly* underscores the presence of this topic in the IS field.

Finally, the findings in this thesis highlight the need for more extensive research on IT-dependent (not just IT-mediated) boundary-spanning practices. The differences between forms of boundary spanning and capabilities in information technology need to be further explored. By combining insights from technology-free (before IT implementation) and technology-based (after IT implementation) boundary spanning, we can gain more detailed knowledge of the role of IT in boundary-spanning practices. The assemblage perspective on boundary-spanning practices presented in this thesis needs to be further extended. An adjacent perspective that can be used to further explore this issue is sociomateriality (Orlikowski & Scott, 2008), which is an emerging stream of research that equally weights the material and the social and thus accounts for both parts. According to the originators of this perspective, “this is a move away from focusing on how technologies influence humans, to examining how materiality is intrinsic to everyday activities and relations” (Orlikowski & Scott, 2008, p 455). Moreover, boundary-spanning assemblages should be validated by further studies of different forms of assemblages.


References


Appendix 1
Examples of interview guides

The following protocols were used to guide the interviews and were not presented to the respondents. Certain questions were adjusted or removed depending on the respondents’ position and work.

Interview guide for case study 1 (MGC)
• Your background?
• Your position?
• Remote diagnostics system project
  • Your involvement?
  • How was the project initiated?
  • Participants?
  • Issues discussed?
  • Next step in the project?
• The remote diagnostics system
  • Current status?
  • What data is collected?
  • How often is data collected?
  • How is data stored?
  • How is data transferred?
  • Who receives the data in your organization?
  • For how long time is the data stored?
  • How do you present the results to the customers?
- Development
  - Current needs of developments?
  - What has been easier/more difficult than expected?
- Experiences
  - Have you been able to detect any errors?
  - Unexpected errors in the equipment?
  - Benefits/disadvantages?
  - Reactions from service technicians?
  - Reactions from customers?
- Remote diagnostics service project (total onboard care)
  - Your view on the new service concept?
  - How was the project initiated?
  - Who runs the project?
  - What has been most difficult?
  - What is new? Is it merely a new packaging of old work?
  - Why develop this new concept?
  - The role of IT for the project?
  - In which services are remote diagnostics used?
  - What do you gain/lose with the remote diagnostics system?
  - Reactions from customers/service technicians/sellers?
  - What does total onboard care mean for MacGregor?
  - Changed work practices?
  - Changed businesses?
  - New insights?
- Customers
  - What responsibility do you have if a breakdown occurs?
  - Customer role in the new service concept?
  - What information do they get?
  - How do they get this information?
  - Who is the service customer? (Ship owner or captain)
  - Customer demands?
  - How convince customers on the value of the new services?
  - Is this a performance based contract?
  - Changes in customer organization/operation with these services?
  - Customer input for a successful service?
  - Customer views on bringing in an external actor and IT?
  - Their view on external data transfers?
Interview guide for case study 2 (PowerDrive and customers)

Interview guide at PowerDrive:

- Your background?
- Your position?
- Management
  - PowerDrive’s business strategies? Current development?
  - IT development strategies?
  - Why remote diagnostics systems?
  - The most important benefit with the system?
  - Who runs the development of the system?
  - Describe the development project?
  - How does the system influence the daily work practices?
  - What new competencies are needed due to the system?
  - How does the organization gain/maintain these competencies?
  - How does the remote diagnostics system strategy fit into the overall business strategy?
  - Next step for the company?
  - New business opportunities with the technology?
  - Obstacles?
- Sales organization
  - Describe the sales process?
  - How is the equipment offered?
  - Is the technology sold as a separate unit or as part of a larger solution?
  - Who has most contact with customers?
  - New business offers?
  - Who has knowledge of customers’ businesses?
  - How is that knowledge maintained and shared in the organization?
  - How many customers have the remote diagnostics system?
  - Why did they install it?
  - How is it working?
  - Current relationships to these customers?
- IT development
  - Development of software for control system?
  - Functionality of the control system?
  - Interface to operators/technicians?
  - Use of remote diagnostics system at the moment?
  - Integration of remote system and control system?
- Maintenance
  - How is it organized?
• What is working well/not so well?
• What does remote diagnostics mean for the maintenance organization?
• How does it influence the work practice?
• How well do you know the customers?

• IT
• In what ways do you get in contact with the remote diagnostics system?
• Describe how the system should be used?
• How has your work changed due to the system?
• How can the system contribute to your work? To the organization?
• Compare your role with the role of technology in the daily work.
• Do you trust the technology? Why/why not?
• What is the worst scenario with remote diagnostics use?
• The best scenario?
• Who is responsible for errors and breakdowns?
• Can you describe the overall technological development in the organization?

Interview guide for the customers
• Your background?
• Your role in the organization?
• IT use
• Describe the use of IT in the production and the products.
• Your knowledge of remote diagnostics systems?
• Where did you gain that knowledge?
• Is remote diagnostics part of your IT strategy?
• Your opinion of the systems functionality, strength, weaknesses, opportunities?
• How can the system support the work?
• Do know of other remote diagnostics suppliers than PowerDrive?
• Who is most affected by the IT investments?

• The remote diagnostics service
• How is the system working?
• How does it affect work?
• Does the system create opportunities/challenges?
• Does it solve any problems?
• How central are these systems for the organization’s operation?
• Does it solve the expected problems?
• What knowledge is required for using the system?
• Why did you choose to invest in remote diagnostics?
- Management
  - What are the dominant factors when investing in new technology?
  - How are these investments decisions made?
  - Why are you investing in IT?
  - Your view on digitalized equipment?
  - Can you describe the optimal IT-use?
  - How close are you to that use?
  - What is needed to reach that optimal use?
  - Your opinion on a close co-operation with PowerDrive and other suppliers?
  - Opportunities/challenges with such co-operations?

- Operation and management
  - How is PowerDrive’s equipment used?
  - What do you do to avoid breakdowns?
  - Describe the current maintenance work.
  - Your opinion of PowerDrive?
  - What service contracts do you have?
  - How can the use/maintenance of PowerDrive’s equipments be improved?

- IT
  - In what ways do you get in contact with the remote diagnostics system?
  - Describe how the system should be used?
  - How has your work changed due to the system?
  - How can the system contribute to your work? To the organization?
  - Compare your role with the role of technology in the daily work.
  - Do you trust the technology? Why/why not?
  - What is the worst scenario with remote diagnostics use?
  - The best scenario?
  - Who is responsible for errors and breakdowns?
  - Can you describe the overall technological development in the organization?

**Interview guides for case study 3 (MCC and Alpha)**

**Interview guide at MCC**
- Your background?
- Your role in the organization?
- Your role in the customer’s organization?
- How do you experience the customer’s view of
• preventive maintenance?
• MCC as a service provider?

• Are the customers satisfied with MCC’s work?
• Your view on responsibility issues?
• Are the customers interested in your work?
• Do they have knowledge of the information you gain in your work?
• What would you like to improve regarding
  • Technology?
  • Business offers?
  • Work routines?

• Customer study
  • What do you know about the customers’ view of MCC?
  • How have you gained that information?
  • What is missing in that view?
  • Is trust essential in the customer relationship?
  • How is it developed?
  • Is it dependent upon certain people?
  • Is it dependent upon technology?
  • How can it be maintained?

• Outsourcing
  • Are you familiar with the term outsourcing?
  • A definition: Organization A allows organization B to perform certain processes. Thereby organization A can focus on its core activities. The reasons can be (a) to save money and increase the profit, (b) difficulties finding qualified workers, (c) difficulties to follow the rapid technological development.
  • Would you say that the customers outsource parts of their operations to MCC? Why/why not?

Interview guide customers

• Your background?
• Your position at the company?
• Remote diagnostics operations
  • How often do you get in contact with MCC?
  • What do you know about their work?
  • What do you know about their organization?
  • What information have you received internally about MCC and their development?
  • How has the remote diagnostics service changed your work practice?
  • Has the maintenance work changed due to the service?
• On a scale from 1 to 5, how pleased are you with the service? Why that value?

• Expectations
  • Your expectations concerning MCC?
  • Why those?
  • What is required by your organization for a successful relationship?
  • Describe the optimal maintenance work.
  • Would you recommend the remote diagnostics service to someone else?

• Value
  • What is the added value with the remote diagnostics service?
  • Can you give two concrete examples of something good?
  • Are there other providers that could replace MCC?
  • Are you dissatisfied with anything?
  • Can you give two concrete examples of something that has not been working?
  • Do you feel a need of controlling MCC’ work?

• Relationship
  • Your opinion of MCC’s treatment?
  • How is daily contact working, feedback etc?
  • Is it important with feedback from MCC? Why/why not?
  • Your opinion on the monthly reports?
  • How is the feedback from MCC managed?
  • Do you give MCC feedback?
  • How can the relationship be improved?

• IT and trust
  • What do you know about condition-based maintenance?
  • Can you describe the technology used by MCC?
  • What do you know about the technology’s opportunities and limitations?
  • Do you trust the technology?
  • Have you thought of the surveillance aspect? Your opinion?