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ORIGINAL ARTICLE

Organizational dimensions of e-maintenance: a multi-contextual perspective

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Abstract A key objective for e-maintenance efforts is to align maintenance processes with business- and operational processes in order to reach organizational objectives. In the context of the process- and manufacturing industry a key objective for firms is to avoid downtime and to make sure all critical production equipment is up and running. To this end, e-maintenance has become increasingly important for the process- and manufacturing industry. Successful e-maintenance is realized by the organizational use of advanced information technology-solutions which aims at moving maintenance work from being primarily reactive (e.g. to react and respond to equipment breakdowns) to predictive (e.g. to predict when equipment are in need of maintenance before it breaks down). Building on a collaborative project with industrial organizations in the pulp and paper and the mining industry this paper explores organizational opportunities and challenges associated with the design and implementation of IT-based services for remote diagnostics of industrial equipment. We observe opportunities and challenges related to organizational innovation and learning. The paper introduces a multi-contextual perspective to better understand the opportunities and challenges associated with organizational learning and innovation. We argue that in order for e-maintenance services to be successful it must not only build on leading-edge technological solutions but also be built on an explicit model for how the maintenance work is organized and how e-maintenance efforts are aligned with overall organizational objectives.

Keywords Preventive maintenance · Remote diagnostics services · Remote diagnostics systems · Multi-contextual · Service delivery

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1 Introduction

Emerging e-maintenance solutions offers a revolutionary change for contemporary organizations as information technology (IT) enables new forms of maintenance of industrial equipment. While previously mainly relying on sensing skills, hands-on knowledge, and closeness to the equipment, traditional maintenance practices are transformed as contemporary e-maintenance practices add processes of electronic information collection and exchange. In the literature e-maintenance is described as a broad concept covering a variety of maintenance related services ranging from diagnostics to quality assurance (Kajko-Mattsson et al. 2010). Remote diagnostics services are a family of e-maintenance services where new maintenance services are enabled by remote diagnostics systems monitoring the equipment's condition (Hibbert 2000; Jonsson 2010). These systems can automatically monitor performance, diagnose problems, and request attention from service technicians for any problems detected (Biehl et al. 2004). The use of such systems has led to a centralization of maintenance activities that were previously arranged locally. Remote service centers can be organized globally, and they can monitor and diagnose a large number of distributed industrial equipment and their components across multiple organizational boundaries. Remote diagnostics systems have generated new insights like brokering leading maintenance practices data, or new maintenance rules. Finally, they increase the information and knowledge intensity of maintenance work, as centralized centers can analyze multiple data sets in complex ways with small additional cost (Jonsson et al. 2009). Technicians in the centers can also focus on proactively diagnosing problems by learning from past cases. Moreover, these systems provide knowledge-intensive value-adding services like learning from failures through rule-based decision-making, or statistical sampling and data mining (Kuschel and Ljungberg 2004; Tolmie et al. 2004).

With remote diagnostics services, no direct user involvement is required in the data collection, as sensors are embedded into the equipments to log their condition, and the subsequent data analysis often takes place at remote service centers by experts. While remote diagnostics systems have been described as an "intelligent maintenance system" (Lee et al. 2006) current research has mainly elaborated on data acquisition techniques (e.g. Collacott 1977), signal analysis (e.g. Allen and Mills 2004; Hayes, 1996; Korbicz et al. 2004), diagnostics and fault detection (e.g. Gertler 1998; Simani et al. 2003). However, intelligent maintenance systems do also raise issues concerning knowledge management and new business services (Lee et al. 2006). Remote diagnostics systems can support transformations of businesses from being primarily product oriented to service and performance oriented with focus on delivering performance (Markeset and Kumar 2005).

For contemporary industries, management, interaction, and interactivity of e-maintenance services is an emerging challenge (Kajko-Mattsson et al. 2010) and this paper seeks to investigate such challenges from an organizational perspective. To meet this challenge, the objective is to explore organizational opportunities and challenges associated with IT-based services for remote diagnostics of industrial equipment. We focus on organizational innovation and organizational learning, which are two perspectives brought forth in boundary spanning literature. Boundary spanning is adopted as a theoretical perspective as remote diagnostics services by default involve the transfer of data across organizational boundaries. We will introduce a multi-contextual perspective as a lens to better understand opportunities and challenges associated with the service related issues surrounding a remote diagnostics service solution.

2 E-maintenance

During the last decade e-maintenance has attracted an emerging interest both within industry and academia (Iung and Marquez 2006; Kumar et al. 2010; Lee et al. 2006; Muller et al. 2008; Tsang 2002). On a general level "e-maintenance is maintenance managed and performed via computing" (Kajko-Mattsson et al. 2010). More contextual definitions try to grasp different implementations of e-maintenance. Karim and Söderholm (2009) define e-maintenance as "the application of ICT for remote maintenance and the representation of the physical world in a digital mode that aims at supplying tailored information as decision-support regarding appropriate maintenance activities for all stakeholders independent of time, geographical location, or organizational belonging". According to Swanson (2001) "e-maintenance replaces conventional reactive strategy by proactive versus aggressive strategies. IT is as revolutionary change rather than evolutionary advance." Kajko-Mattsson et al. (2010) puts attention to the service aspect in their contextual definition; "e-maintenance is a multidisciplinary domain based on maintenance and information and communication technologies ensuring that the e-maintenance services are aligned with the needs and business objectives of both customers and suppliers during the whole product lifecycle". As these different definitions show e-maintenance is a broad field that covers a variety of issues related to the use of IT in maintenance.

E-maintenance technologies increase the possibilities (1) to utilize data from multiple origins, (2) to process large volumes of data and make more advanced reasoning and decision-making, and (3) to implement collaborative activities (Iung et al. 2009). In remote diagnostics services these possibilities are utilized to enable new businesses.

2.1 Remote diagnostics services

In maintenance-related services, one key facet involves improving customer up-time (Armistead and Clark 1991), as failures in maintaining equipment and subsequent breakdowns can cause production problems and ultimately also environmental hazards. These problems and hazards can be minimized if machinery failures can be predicted and corrected proactively. The aim of preventive maintenance is to replace components before a failure occurs, in contrast to a run-to-failure approach where maintenance is done after the fact (Tsang 2002). Two main approaches to preventive maintenance are scheduled maintenance and condition-based maintenance. In the former, maintenance is performed at scheduled intervals regardless of the item's actual condition. In condition-based maintenance, actions are performed when failure is deemed to be imminent. Performance-parameter analysis, vibration monitoring, thermography, and oil analysis are typical monitoring techniques that are used in condition-based maintenance. The challenges involved with condition-based monitoring include installing sensors that observe such conditions, maintaining the history of collected data to predict when a failure is imminent, and communicating this to the relevant parties. These challenges are increasingly related to organizational issues and abilities.

Condition-based monitoring can be transferred, by means of new IT, to remote field sites. These sites provide remote services organized around ongoing information gathering and exchange, and allow for remote access to machinery components (Simmons 2001). The IT infrastructure for remote diagnostics services consists of the remote diagnostics systems, which carry out continuous sensing, collection, transfer, and analysis of the machinery's condition parameters (Jardine et al. 2006). These systems are organized around rich forms of digital data gathering and exchange (Simmons 2001) allowing for extensive, real time, and model-based computations. Remote diagnostics systems are made up of collections of heterogeneous technologies; sensors that collect data, networks that transmit it into a centralized repository; and analytics and operational rule systems that store and retrieve the data, analyze it, visualize it and make recommendations, generate alarms, or launch responses. The sensors are distributed among critical physical components throughout a plant, or an industrial network (Han and Yang 2006). Depending on which types of sensors are installed, 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 find problems in the equipment early on. With sensors embedded in the equipment it becomes possible to go beyond object identification and measure the status or condition of products (Hackenbroich et al. 2006; Han and Yang 2006). Object location, temperature, and acceleration are examples of parameters that can be measured. The monitored parameters can indicate changes months or even years before a breakdown will occur, and the remote diagnostics services are thereby oriented towards a long-term focus. However, remote diagnostics services are not solely based on technology. The remote technicians play an important role in analyzing the collected data, and reporting and discussing the findings with the local workers. These local workers are important for the quality of the service, as they are responsible for maintaining the products and have knowledge of and information about environmentally related issues. In addition, the remote diagnostics services do not fully replace traditional preventive maintenance, as scheduled maintenance is still needed and local interventions are necessary in cases of emergency. To this end, we need to probe deeper into the organizational issues surrounding remote diagnostics technology. The organizational setting in which these technologies are immersed need to be sensitive towards both the opportunities and the challenges associated with remote diagnostics technology use if e-maintenance practices are to be successful.

3 Boundary-spanning IT

While information is critical for most organizations today, accurate information is essential but relatively difficult to gather as boundaries hinder the free flow of information (Tushman and Anderson 1986). 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 and Zander 1992). Consequently, organizations increasingly develop and engage in boundary-spanning activities 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).

Various kinds of information systems support boundary spanning as IT artifacts can be 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).

Lindgren et al. (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, on the other hand, views boundary spanning as essential to organizational learning and typically recognizes boundary spanning across internal boundaries of the organization aimed at situating information in the context of local work practices. In what follows we will analyze the field data from a remote and local perspective to understand boundaries and boundary spanning in the contexts involved in remote diagnostics services. The organizational innovation and everyday work practice perspectives are then applied to further understand the organizational opportunities and challenges associated with IT-based services for remote diagnostics of industrial equipment.

4 Study approach

This paper presents overall findings from two different case studies in processing and manufacturing industry. The first case study was initiated at PowerDrive, a manufacturer of hydraulic drive systems, in February 2003. The overall aim with the project was to evaluate PowerDrive's remote diagnostics service. In order to evaluate the customer view of the service, two organizations, Alpha and Beta, were chosen to represent the customer perspective. The project ended in November 2003 and the results were presented at PowerDrive in March 2004. The second case study was initiated at Monitoring Control Centre (MCC), in April 2004. MCC is a provider of remote diagnostics services and in 2004 we conducted a number of interviews to get an initial understanding of MCC and its remote diagnostics services. In 2006 an in-depth study was conducted to explore the service both from a supplier and a customer perspective, Alpha represented the customer side.

The different organizations in the case studies were selected for several reasons. First, all utilized remote diagnostics services for maintenance, either as a provider or as customers. Second, the organizations represented both the remote and the local work settings, enabling the study of both ends in the 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 for multiple sources of data, and the possibility of purposeful sampling (Peppard 2001; Yin 2003).

Empirical data were collected through interviews, documents and observations. The interview material and field observations constitute the major corpus of the empirical database. In all, 51 interviews were conducted with 42 respondents. The interviews were semi-structured, we had a number of issues with related questions that guided the interviews, but we were open for follow-up questions and issues raised by the respondents. In all cases, a report summarizing the study was written and handed over to the respondents.

5 Results

The empirical context for this study is maintenance work in industrial organizations. While the role of IT in industrial organizations has been investigated extensively (Holmström et al. 2010; Zuboff 1988) relatively little attention has been payed to remote diagnostics technology (for an exception see Jonsson 2010; Jonsson et al. 2009).

As remote diagnostics systems create a digital representation of the physical world, remote service technicians can be grouped in central repositories where data from different remote settings are integrated. Based on data analysis the remote technicians provide the local maintenance workers with detailed information on the equipment's status, serving as decision-support regarding the appropriate maintenance activities. In this section the work of remote and local maintenance groups are explored empirically. First a remote perspective is applied to understand the work conducted at a distance from the object of work. A local perspective is thereafter applied to explore the context where the object of work is physically located.

5.1 Remote maintenance work

With remote diagnostics systems installed as a link between the remote maintenance technicians and the equipment, data can be captured and transferred to the remote service centre for analysis. Transfer of data from many dispersed objects into one place enhances the possibility of comparing data and the technicians performing the analyses gain experiences from many different equipment and settings. These systems can for instance collect data on vibrations from bearings, temperature, pressure and speed. By monitoring such parameters the system helps finding potential problems in the equipment before they lead to a breakdown.

Compared with information retrieval via phone or data collected with hand-held devices the remote diagnostics system is viewed as creating a stable and regular flow of data. The service providers view data automatically collected as reliable due to the stability in the data collection process. Moreover, the service providers witness about how sensors also expand human sensing as they can monitor things which humans cannot and in places where humans cannot go. For example, a sensor can pick up sounds, which the human ear cannot recognize. Another benefit highlighted by the service providers with the remote diagnostics system is the possibility to get access to data when the equipment is in use. Due to machine design and safety regulations it is sometimes impossible for humans to get inspect the equipment while they are running.

The remote service providers in this study underscore the possibility of providing a seamless service solution based on the system's continuous monitoring of the equipment. For equipment manufacturers, as PowerDrive, remote diagnostics systems is an enabler of new after-sales business, while at the same time giving them important feedback about their equipment in use. Traditionally, PowerDrive had to send out a technician to the customer site to check the equipment's status, but with the remote diagnostics systems real time data can be accessed at a distance.

The remote diagnostics system enables a seamless flow of data concerning monitored parameters between the local and the remote site. It also shows what has happened in between the service visits:

> With the remote diagnostics systems we can see things between the physical visits. For example in England we could see that one motor worked under very high temperature. When the technician was there everything was ok, but the system told us that every night the temperature increased dramatically. It was due to a regular overload of the motor and nothing that we could detect during our physical visits day-time. (Technical engineer, PowerDrive)

At PowerDrive the possibility to get feedback was one of the driving forces in the development of the remote diagnostics system. PowerDrive can now receive richer information from its products work in real settings. The previous boundary between the manufacturer and the product used in the local context is more porous:

> We do not know how the customers use our products if we don't monitor them during operation. (Technical engineer, PowerDrive)
> If there is a problem we can log in and see how things look right now. Have they made any changes, is the parameters in the motor the same as when it was delivered? The system gives a clear picture of the motor at the moment. (Design manager, PowerDrive)

With the remote system it is also possible to learn more about how the products operate in real work conditions. This knowledge is valuable both for product development, but also in improving customer's use of the product. Earlier the manufacturer could inspect the product only while it was idle.

> […] it's easy to see how the whole drive system is being used, if it is running as planned and if it is correctly dimensioned. This will provide a useful overview of how the complete drive system is being used helping us to understand drive applications better, improve settings and achieve better performance and more efficient utilization. (PowerDrive customer magazine, 2-2003)

Even though MCC is not a manufacturer they offer similar remote diagnostics services as manufacturing companies. The company is located in the northern part of Sweden but envisions becoming a global service provider of remote diagnostics services. A technician at MCC says that:

> We are able to monitor a machine at a company in Africa, it is just to plug in the cable. But I think we must have a good contact with someone at that company. (Technician A, MCC)

The remote diagnostics system enables a global monitoring of machines as long as data can be transferred from the local site to the remote work setting. However, as the technician mentions the contact with the workers at the local site are important. The remote worker is limited to the information that is received via the system and additional information can only be given by those who are present in the local environment. For the remote worker data is the key for finding problems in the equipments and prevent unplanned breakdowns. However, the service providers in this study see a challenge in selecting parameters and time intervals for monitoring. In one way they are all seduced to collect more and more data to get a more all-embracing model of the products, which enables crosschecking of parameters if uncertainties arise. However, even though increased data collection can minimize uncertainties and give more information about the products, all organizations stress the risk of information overload as the amount of data is growing fast, and sometimes faster than they manage to handle.

As the remote diagnostics system enables detailed monitoring of how the equipment is operated it also indirectly enables monitoring of the operators. MCC is aware of this capability:

> This is to a large extent a surveillance system. We have taken temperature measurements on drills and with that data you can see exactly how the machine is operated, how long the breaks have been and how long it takes between every shift until the machine is turned on again. (Employee, MCC)

However, the system is not used for this kind of monitoring and no analyses are conducted with such purposes. But, as the system do bring such a capability it might become a critical issue to manage. By embedding technology into equipment at the workplace it becomes invisible for the employees. The literal embeddedness of the technology distinguishes embedded computing from traditional desktop computing. From a user perspective this development brings with it a lack of choices; it is no longer possible to turn the computing device on and off. Moreover, the users may not even be aware of the computer hiding in their everyday artifact, and even if the users are aware of it they may not know why it is there or what data it collects.

5.2 Local maintenance work

Even though the remote diagnostics systems create new opportunities for remote service providers there is also a local perspective that needs to be addressed. The local perspective puts attention to the setting where the equipments are physically located. The traditional maintenance organization performs urgent services and repairs on a daily basis. As both customer companies in this study have a preventive maintenance approach the work also includes services on a regular basis and manual inspections intended to identify potential problems and avoid unplanned breakdowns.

For the local maintenance organization the system per see is invisible. The sensors are embedded into the equipment and data can instantly be transferred via digital networks. The local organization receives monthly reports where the status of the equipment is presented. Moreover, the remote technicians inform the local workers about the product status via phone, especially if they detect something urgent. The service providers and the plants' management think it is important that the work of the local group sustain, however, with assistance by the remote technicians.

All organizations in this study highlight that even though the equipments are constantly monitored with remote diagnostics systems, only data from a specified number of parameters are collected. Thus, the picture a remote technician gets is not total. The diagnoses that can be performed with the system are only based on the parameters that are monitored. A physical walk-around by an experienced technician who can see, hear, and feel when something is abnormal can detect things that the technology and the remote technician cannot. A technician at Beta also says that:

> You have to learn to know the machines individually. You do not do that remotely. (Technician A, Beta)

This highlights a clear limitation with the remote diagnostics systems compared with the work of an experienced technician walking around in the plant. Although the system can detect conditions that the local technician cannot, many of the respondents point out the importance of keeping in mind that there is a world out there and the collected data on its own is not enough. The technician at Beta expresses both a risk and a limitation of the technology:

> With more monitoring, you can work more and more online and less people will be out among the machines. You won't get the same feeling of the machines. The only things you see are, for example, temperature, pressure, and flow. You do not know how it sounds. (Technician A, Beta)

The system and, therefore also the remote technicians, are limited to the data collected by the sensors. The limited depiction of the reality is a constraint that always has to be kept in mind and considered. Besides this limitation with the remote diagnostics systems the technician also mentions an important effect of the systems—with more online measurements the less people will be walking around by the machines. At Beta they gave an example of problems with a motor due to bad oil quality—a parameter that the remote system did not monitor. After repeated problems with the motor a technician finally cheeked the machine physically, and the problem was identified. Another example is given by Alpha that also highlights the loss of local presence for the remote workers. An engineer at the company described how they installed a remote diagnostics system in one of the oil pumps that monitored the oil level. When the oil level sank, a remote technician called the operator and instructed him to fill up more oil. This system was supposed to be a complement to the operators' traditional regular walk rounds in the plant. After a while the operator got used to the phone calls and sometimes neglected to walk around in the plant. The system, however, only measured the oil level and did not give the remote technician an overall depiction of the equipment and its environment. Once it almost broke down due to problems that the system could not detect: but the operator would if he had walked by the machine. In this case the remote diagnostics system led to a local physical distance as the value of a local presence were not realized. To the operator, the phone calls from the remote technician had become a work practice that would indicate all problems with the machine and, therefore, the walk rounds were neglected. This shows that through the use of remote diagnostics systems follows the critical issue to manage the boundaries between the remote and local maintenance work. Not only must the remote centers be well functioning, the local maintenance work must also be managed when implementing remote diagnostics systems.

6 Discussion

The objective of this paper was to explore organizational opportunities and challenges associated IT-based services for remote diagnostics of industrial equipment. We theorized boundary spanning as a central explanatory mechanism through which the outcome of e-maintenance work can be explained. Data from two case studies in the processing and manufacturing industry were used to illustrate this mechanism.

The findings show how remote diagnostics systems are ushering in a new distributed and networked knowledge-intensive industrial organization, that re-organizes production functions and their control geographically based on the creation and distribution of new knowledge-based operational skills. Moreover, they foster untried ways to organize production and its maintenance that separate local information from its origins and make it travel so as to permit centralized operators to act from a distance. They establish unprecedented knowledge-based routines that separate technicians in time, space, and industrial context from the components they monitor. These changes enable new value creation processes (Jonsson et al. 2008) and information flows across boundaries (Jonsson et al. 2009), but also challenges manufacturers to adapt a service focus (Markeset and Kumar 2005).

Lindgren et al. (2008) distinguish between 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 remote diagnostics practices. Table 1 summarizes these findings from the viewpoints of the service provider and the customer.

Enabled by remote diagnostics technology, the service providers can now engage in real-time knowledge creation regarding the equipment in use in multiple contexts. Before the use of the remote diagnostics system, different technicians conducted separate inspections 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. Through remote diagnostics of the equipment, the service providers also obtained deepened knowledge of the maintenance processes. 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. 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 et al. 2007). The manufacturer's deepened insights regarding maintenance can also lead to changes in recommendations regarding when the equipment should be maintained. When the service provider is the equipment manufacturer, the information gained from the system can be used directly for development of the equipment. 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 central service centers with knowledge from many external settings can be created. Moreover, customers may seek to reorganize their maintenance organization and outsource the diagnostics portion to focus on other processes. Based on the information gained via the remote diagnostics system, customers also change their maintenance routines and their use of the equipment.

As this paper 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 and 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 these type of systems allow for collection and

Table 1 A multi-contextual perspective on remote diagnostics practices

Organizational context	Organizational learning	Organizational innovation
Service provider	Knowledge of equipment in use in multiple settings	New business services Changed maintenance recommendations
	Deepened knowledge of equipment maintenance	Equipment development
Customer	Knowledge of equipment in use Improved knowledge of maintenance	Outsourced maintenance services Changed maintenance routines Improved use of equipment

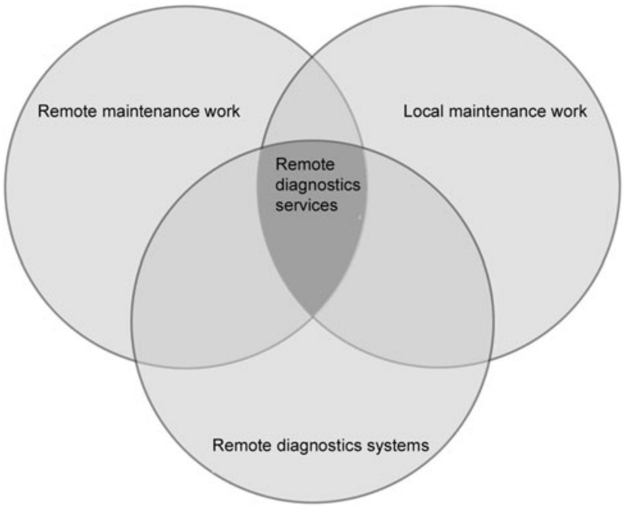

Fig. 1 Remote diagnostics services

transfer of contextual information that is useful from both a work practice and an organizational innovation perspective. However, this thesis adds the perspective of multi-contextual 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 and 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.

As this study shows the adoption of a remote diagnostics service is not merely an issue of managing technology. Rather, it requires a broad organizational approach where the local maintenance work as well as the remote maintenance work is managed as well. Figure 1 illustrates this perspective, underscoring how the adoption and use of remote diagnostics services is not merely a technological issue but rather deeply intertwined with managing the remote as well as the local contexts.

This perspective brings a focus on the surrounding where the technology is installed. If the remote and local contexts are not well functioning the potential of remote diagnostics services is not fully explored. Hence, e-maintenance development is a development of technology as well as new work processes, routines and information flows rather than merely a technological development process.

7 Conclusions

This paper proposes a holistic view of e-maintenance service development. From a multi-contextual perspective we argue that a successful organizational use of advanced IT-solutions can help to move maintenance work from being primarily reactive to predictive. In other words, e-maintenance work can predict when equipment is in need of maintenance before it breaks down, instead of react and respond to equipment breakdowns after the fact. Based on studies of remote diagnostics services we identify organizational opportunities and challenges associated with the implementation and use of these services in industrial organizations. These services offer many possibilities for new and improved maintenance processes, but they also bring many challenges that need to be managed. In order to address the challenges and opportunities related to emerging e-maintenance practices in process- and manufacturing industries, organizational issues must be conceived as central, and entangled with the emerging technologies that these organizations are putting into use.

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