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Enhancing field-service delivery: the role of information

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Abstract

Purpose – The purpose of this paper is to examine how the availability of information on the equipment to be serviced affects field-service delivery performance.

Design/methodology/approach – The research was performed as a case study with a capital goods manufacturer and its service network. The analysis is based on interviews, a survey of companies in the service network, and warranty records.

Findings – In the case setting, it was found that 40 percent of failed service visits were caused by a lack of information. In addition, almost one third of the service visit's duration was used to inquire for detailed information on the equipment in order to be able to diagnose the problem. Preparation of the on-site visit is identified as a critical information enabled step for high performance field-service delivery. In the studied case setting, access to reliable information would significantly improve the service call success ratio and shorten duration of on-site service operations.

Research limitations/implications – The results on the importance of equipment information for the preparation of the service visit are indicative, as the findings are based on a single case study. Further research is needed on how users, service companies and original equipment manufacturers can collaborate on improving availability of equipment information to enhance performance in field-service delivery.

Practical implications – Service call success ratio is one of the most significant cost-saving opportunities in field-service delivery. The paper shows how introducing an information-enabled preparation step before making the service call can significantly improve service call success ratio, reduce maintenance costs, and improve equipment uptime.

Originality/value – The paper presents an empirical study highlighting the importance of equipment information in preparations performed prior to accessing the servicing site in field-service delivery.

Keywords Service operations, Service calls, Service improvements, Information management, Field service, Equipment information, Service call success ratio, Service call preparations

Paper type Case study

Introduction

The benefits of informational support systems in maintenance services are widely recognized. As early as in 1988, Ives and Vitale claimed that information systems could be a significant factor in improving maintenance service. More recently, Agnihothri *et al.* (2002) among others have pointed out the usefulness of information systems in maintenance. However, in the literature on information facilitated maintenance, the focus is on sophisticated systems and maintenance solutions, such as condition-based maintenance (CBM) (e.g. Ives and Vitale, 1988; Tsang, 1995; Veldman *et al.*, 2011), problem-diagnosing tools (e.g. Christer and Whitelaw, 1983; Ives and Vitale, 1988; Pintelon *et al.*, 1999; Gao *et al.*, 2007), and life-cycle information acquisition (e.g. Marsh and Finch, 1998; Simon *et al.*, 2001; Songini, 2004; Karim *et al.*, 2009).

While the value of these sophisticated approaches must not be understated, there is a need to better understand the effect of better information in different types of operational settings (Roth and Menor, 2003). As already Marsh and Finch (1998)

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pointed out, even providing the most basic product information for the service personnel is a challenge in the heterogeneous operating environment of field services. Service delivery in the field poses quite different challenges than in the more controlled production environment of a dedicated service facility, such as a repair shop. In the field delivery performance entails fixing the customer's problems on site, regardless whether a service call is triggered by the condition of the equipment, a maintenance schedule, or an equipment breakdown.

In this paper, we present empirical results on the availability of equipment information for performing field-service operations. The effect of lack of information on field-service performance is studied in a case study in electrical investment goods industry. In addition to qualitative effect descriptions, the improvement potential is demonstrated by quantifying the impacts in terms of service call success ratio and on-site time usage. Based on our case study, we propose that availability of information in on-site operations is one of the most critical elements for improving service delivery in the field.

The paper is structured as follows. In the first part, we discuss relevant maintenance literature addressing maintenance policies, equipment downtime, and information needs in maintenance operations. In the second section, we describe the research design of this study. The third part presents the results of the study, followed by conclusions and further research suggestions.

Literature review

Maintenance environment

The primary objective of equipment maintenance is to preserve system functions in a cost-effective manner (Tsang, 1995). Under this general goal, different parties have their own objectives for maintenance and that is why maintenance performance should be measured from several viewpoints (Parida and Kumar, 2006). Consequently, maintenance performance measures can be divided into three general categories (Campbell, 1995): first, equipment performance; second, cost performance; and third, process performance. From the equipment user's viewpoint, the most important goal of maintenance is to minimize the downtime of equipment. This is the equipment performance standpoint. For a manager of a maintenance organization, the interests are also in maintenance costs and efficient execution of the maintenance process. These represent cost performance and process performance standpoints. In this paper, the focus is on process performance in field-service delivery. Improving process performance typically enhances cost performance and equipment performance and is therefore a very important measure for a field-service organization.

The objectives of maintenance can be pursued using different maintenance policies which all aim at reducing the equipment downtime. These policies can roughly be divided in corrective maintenance and preventive maintenance. In the former case, maintenance operations are carried out after an equipment failure has been identified, while in the latter group the goal of operations is to replace equipment or return it to good condition before failure occurs (Hill, 2000; Tsang, 1995). Preventive maintenance methods are further divided to scheduled maintenance methods and CBM methods (Yamashina and Otani, 2001). Scheduled maintenance is achieved when maintenance tasks are performed following a time or usage-based schedule. Optimal schedules can be determined using quantitative decision models, but usually they are only drawn up on the supplier's recommendations on mean failure times (Hill, 2000; Tsang, 1995).

CBM is a more sophisticated type of preventive maintenance relying on monitoring and analyzing information on products in use (Tsang *et al.*, 2006). The condition of the item is monitored continuously or intermittently to carry out preventive maintenance actions only when failure is judged to be imminent. Thus, replacing or servicing equipment prematurely can be avoided. Decision when the maintenance task is carried out is made based on the condition-monitoring techniques, such as vibration monitoring, process-parameter monitoring, or thermography (Tsang, 1995).

However, despite that the preventive maintenance policies are designed to reduce the number of equipment breakdowns and reduce the uncertainty of downtime by planning in advance, equipment breakdowns cannot be totally eliminated. There are trade-offs between the costs of scheduled maintenance or condition monitoring and the costs of a breakdown. The aim of maintenance policy selection is to find the most cost-effective strategy over the lifecycle of an asset (Löfsten, 1999; Tsang, 1998). When striving for optimal maintenance costs, different parts of a production facility most likely require different maintenance policies (Yamashina and Otani, 2001), thus potentially leaving some equipment to be serviced only in cases of breakdown. Also, breakdowns cannot wholly be eliminated with preventive maintenance measures. Scheduled maintenance is often based on either measured or supplier-specified equipment mean time between failures, but in reality the failures take place at random times, and therefore breakdowns will at times happen between scheduled maintenance actions (Pillay *et al.*, 2001). Also, with CBM it is to be noted that no inspection or monitoring can be 100 percent effective, as the condition needs to be identified correctly, and the symptoms of a failure are not always noticed (Crocker, 1999). Further, the opportunity window between the emergence of abnormalities and consequent failure may be too short for the symptoms to be recorded in an inspection or monitoring process (Pillay *et al.*, 2001).

The implementation of sophisticated maintenance strategies can be difficult in companies with established maintenance traditions. A study of four manufacturing firms in the UK indicated that in practice many advanced maintenance philosophies are not adopted fully in organizations, as the service technicians may remain unfamiliar with the concepts. As a result, planned maintenance activities give way to short-term needs of keeping the plant running, which results in firefighting activities and breakdown maintenance (Cooke, 2003). Thus, corrective maintenance in the form of breakdown repairs is not always a deliberate choice, but rather results from ignorance toward maintenance planning (Hipkin, 2001).

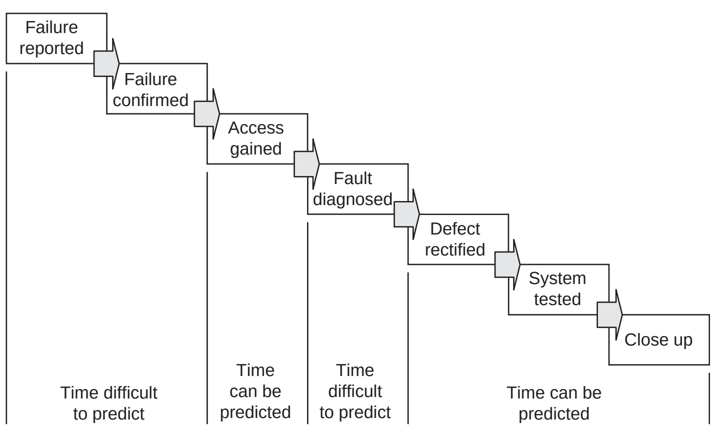
What makes the above notions important is that downtime is especially problematic for equipment that breaks down, either inadvertently or due to a commitment to corrective maintenance. First, such equipment easily experiences a longer downtime than equipment that is intentionally shut down for servicing, as all preparations needed for the repair have to be performed during the downtime. Second, the resulting unplanned downtime of equipment is often far more costly than planned stoppages due to loss of committed production, decrease in quality, and inefficient use of facilities, equipment, and personnel (Ashayeri *et al.*, 1996). For example, in hourly downtime costs for production systems have been quoted from between 1,000 USD up to 100,000 USD in the chemical industry (Löfsten, 1999; Tan and Kramer, 1997). Due to these consequential costs, reducing the downtime in cases of equipment breakdown can be very profitable.

The effectiveness of the repair process is especially important, when considering field-based maintenance as opposed to facility-based maintenance. In field-based maintenance, i.e., field service, it is the responsibility of the service provider to perform maintenance operations to the equipment located at a customer's site (Agnihothri *et al.*, 2002). The opposite approach is facility-based service, where customers access the service facility and where it is feasible to warehouse scores of spare parts as back-up and have a variety of tools and documentation available at the service facility. This is not possible in field-based service, which makes it necessary to prepare in advance for the operations (Auramo and Ala-Risku, 2005). Indeed, it has been stated that the probably most typical problem in field service is not having the correct spare part available on site (Maynard, 1997). In the following, we refer to the execution of field-based maintenance-service operations shortly with the term field-service delivery to emphasize the importance of logistics and preparation of the service supply chain.

Field-service delivery and equipment information

According to Knotts (1999) downtime, i.e., the time it takes to rectify a defect, consists of four main phases: first, detection that a problem exists; second, gaining access to the equipment; third, diagnosing the problem and locating the cause; and fourth, taking necessary corrective action (Figure 1). Knotts argues that there are differences in the predictability for the durations of the different steps of defect rectification time. He explains that time covering access, defect rectification, and test and close up can be forecasted based on either experience or predictive techniques using time standards. On the contrary, the problem detection and fault diagnosing times are difficult to predict. Knotts argues that the unpredictability arises from non-standardized procedures and lack of time prediction techniques covering fault diagnosis and isolation. His decomposition of downtime is especially useful when evaluating the impact of information input on the service delivery process.

In each of the process phases, decisions are made influenced by some characteristics of the serviced equipment. The quality of the decisions depends on the information available on those characteristics. Consequently, information and the use of information is a critical in organizing a high-performance service production process (Knezevic, 1999; Sampson and Froehle, 2006). The problem of accurate information in field-service delivery has been recognized in a case study noting that subsequent



Source: Knotts (1999)

Figure 1.
Components of defect rectification time

equipment failures have been found to be caused by mistakes of service technicians due to lack of information on correct procedures and parts (Crocker, 1999). However, the role of information in field-service deliveries has not been a particular focus area of researcher. The forum for discussing these issues and their potential solutions are reports on support systems for distinct service process phases that are typically published in non-academic trade journals, such as *Frontline Solutions* and *Computerworld*.

Condition-monitoring systems are important in the problem detection phase and have been extensively covered in both trade (e.g. Liedman, 1998; Kozak and Shinpaugh, 2005) and academic journals (e.g. Karim *et al.*, 2009). Applications have been reported from various industries including automobile manufacturing, power industry, aircraft industry, and ship engine maintenance. For the fault diagnosis and corrective actions phases, the informational tools include technical documentation in electronic form as well as tools that take symptoms and some other parameters as input information, and based on a knowledge base suggest what the probable failure reason is (Ives and Vitale, 1988; Albright, 2000; Marsh and Finch, 1998; Zackariasson and Wilson, 2004; Tsang *et al.*, 2006).

The support systems discussed for the access-gaining phase are related to routing the service resources and service call management (Albright, 2000; Blakeley *et al.*, 2003; Hamblen, 2005; Townsend and Widener, 2004). The equipment information in these systems includes the physical location of equipment along with details about ownership and personnel skills requirements.

Despite the number of reported support systems and tools there is a lack of empirical studies on the impact that more accurate information might have on the effectiveness of for service deliveries in the field (Agnihothri *et al.*, 2002).

Research design and data

As the implications of information availability in field-service delivery have not been addressed in sufficient detail, we pose the research problem: How can field-service delivery be improved with better equipment information availability? In order to study both the mechanisms of information impacts and the magnitudes of those impacts, we seek answers for the following research questions by means of a case study:

- How does missing equipment information affect field-service delivery performance?
- What are the most critical pieces of information required in the field-service delivery process?

The purpose of the first research question is to determine what kinds of performance efficiency losses the unavailability or incorrectness of information may incur. We chose to study the process impacts of information unavailability rather than information availability, as the performance contribution of available information is difficult, if not impossible, to identify among other performance contributing factors. The efficiency losses will be quantified in terms of service call success ratio and service visit time usage. With service call success ratio we mean the share of servicing jobs that are accomplished during the first-service visit. The second research question seeks to define the unavailability of which particular pieces of information is causing the problems. That way it is possible to give recommendations on how the information availability could be improved.

As discussed in the previous chapter, breakdown maintenance and field-based maintenance service form a challenging environment where the requirements for information to manage and reduce downtime are high, once the equipment is broken, all the time used to decide on correct repairing resources (tools, spare parts, and skilled personnel) adds to the total downtime of the equipment and with field-based maintenance the downtime is greatly increased by erroneous decisions on the resources, as corrective actions often involve returning to the service provider's office and accessing the site anew at a later time. On the other hand, such an environment provides a good research platform to study how maintenance service deliveries can be helped with better information, and thus our study was conducted with a manufacturer whose service company network is operating in such a challenging environment.

The focal case company of the study is a capital goods manufacturer providing cooling systems for commercial use and operating mainly in Europe. Its customer base includes hundreds of companies of various sizes who utilize the case company's products in their own operations. The equipment manufactured by the case company can be divided into two categories: small-scale and large-scale cooling systems. The large-scale cooling systems are fixed and fitted to a particular site. The small-scale systems are mobile and can be transferred to another site if required.

The maintenance services are outsourced by the case company to a network of accredited service companies that primarily provide corrective maintenance, where customer personnel order service on a piece of equipment when it does not work properly. Only for a few customer sites has a service partner of the case company made a maintenance agreement for CBM or scheduled maintenance. At the time the research was conducted only the large-scale systems could be equipped with electronic controller systems that enable remote diagnostics and CBM functionalities.

The context of this case setting enables us to examine the effects of different levels of availability of information in an environment where the field-service delivery is highly time critical. In some situations, there was a maintenance agreement between the customer and a service company. Furthermore, also CBM or scheduled maintenance was practiced in some situations.

The case research was carried out using a case study methodology combining data from interviews, a survey, and database analyses. The case setting was first studied in detail based on 19 interviewees at the focal company, service companies, and end customers of the focal company. Most of the interviews were performed with two researchers to guard for interviewer bias by allowing comparisons of interview notes and perceptions. After agreeing on all interview items, the interview memorandums were stored in a case study database for later analysis.

The interviews were used as input for designing the survey questionnaire. The survey was targeted to the Finnish service company network of the focal capital goods manufacturer including 56 service companies with a geographical coverage of the whole country. The questionnaire used in the survey consisted of open-ended questions and multiple-choice questions which were used to collect both qualitative and quantitative data. The questionnaire had two main parts. The first part concentrated on the service operations and the implications of poor availability of information. The second part aimed to find out what information would be needed for better performing field-service delivery. Before conducting the survey, the questionnaire was tested with three service companies whose feedback was used to revise the questionnaire. Each company was contacted by phone beforehand and the questionnaire was delivered by mail, e-mail, or fax, based on each of the respondent's preference. All non-respondents were contacted again after the initial deadline for returning the questionnaire. The response rate was 55 percent, or 31 responses. The respondents were mainly service managers and company owners.

The respondents diverged in terms of their scope of servicing activities and the company specialization. The service partners were mostly small companies, with 75 percent employing between one to three service technicians, and with the largest employing between 50 and 80 service technicians. The number of service calls per week was low, with two-thirds having ten or less service calls per week, and one in seven having more than 20 service calls per week. In addition to the differences in the scope of the servicing activities, some of the respondents had other lines of businesses in addition to the field service of the focal company's products. Based on the survey, field service was an important or very important line of business for 70 percent of the respondents. The other respondents considered installation, rather than service as their main line of business.

The case data used in the analysis was provided by company representatives and is as perceptions and estimates only indicative measure of performance in service operations. Nevertheless, the use of several complementing sources of data enabled the assessment of the data. After the survey was carried out, the results were validated in discussions with experts from the original equipment manufacturing company. Results were also compared with warranty invoicing data of the equipment manufacturer. All the service invoices and reports from a five-month period were analyzed, including 83 invoices from 23 service companies. For the service visit success ratio and on-site time use the results from the survey data was validated by the warranty invoicing data. A comparison of the two data sources gave 79 vs 75 percent for service visit success, and for on-site time use corrective actions took 2.6 vs 2.4 times longer than fault diagnosis.

The problem of measures (especially service visit duration) having a high inherent variance, was identified by the interviewees and also evident in the warranty data. Nevertheless, for the purposes of this study the means of all respondents are used to indicate the direction and magnitude that the availability of different types of information would have on field-service delivery.

Findings

The exchange of product-related information between the case company and its accredited service partner network is a major source of problems causing both inefficiency in the service operations of service partners and dissatisfied customers. The presentation of the findings follows the structure of the process indicated in Figure 1.

Problem detection phase

According to the interviews, there are three main triggers for the field-service delivery process. The most common trigger is a customer call, which results from users observing that the equipment is not working properly or from automatic condition-monitoring devices setting off an alarm that notifies the user of a problem. The second trigger is a contractual one: a customer and a service company have signed a scheduled maintenance service contract, which obliges the service company to regularly service the equipment. The third trigger is the least used: service personnel observe abnormal operation of equipment using remote condition-monitoring systems.

According to the interviewees, prior to access-gaining phase, the service technicians load the necessary spare parts and documents to the service vehicle when leaving from the workshop. This is a highly information critical phase with three main sources of information: remote monitoring, customer order, and companies' own records.

However, based on the survey, there seems to be inadequately data available for the preparations.

In the interviews, service technicians commented that by using the remote condition-monitoring system, the likely defect might be recognized before accessing the customer site. The survey was used to determine how often this information is available. Based on the answers, 41 percent of the service companies had access to remote monitoring information. For two companies, this information was available for over 70 percent of the equipment serviced, and for the rest of the companies gaining this information, it was available from 4 to 25 percent of the equipment serviced. As a result, despite the recognized value of remote monitoring information, it often was not available.

In the survey, we inquired how often different pieces of information are gained from the customer who orders the service. We found out that information on the type of the product was acquired most often, on average in 66 percent of the service orders. Description of the failure was gained in 51 percent, and equipment's manufacturer in 44 percent of the service orders. Other information items were obtained much less frequently. Information on the equipment's service history, previously installed spare parts, and model were available in about every fifth service order, and equipment's serial number is gained less than in every tenth service order.

A third information source is the service companies' own records. In the survey, 71 percent of the service partners kept paper records on equipment locations and only 11 percent kept electronic records. In principle, these records could be used to identify the piece of equipment to be serviced and thus help in effective preparation, but in the case setting there was no indication of this use. Neither the service companies keeping paper or electronic records on equipment locations were performing better than the companies not keeping records.

In the case setting, none of the service companies had access to comprehensive information on equipment and equipment locations. In addition, only remote monitoring could provide the technicians with accurate advance information on the condition of the equipment, but this information was not available often. The implications of improper information prior to the access-gaining phase was noticeable in the later steps of the field-service delivery process.

Access-gaining phase

The access-gaining phase does not employ equipment-related information. The performance in this phase, i.e., the time it takes to access the site, depends on the service level that the companies are offering and it is agreed upon in the service contract. However, based on the interviews, the servicing companies have diverging geographical coverages, and this influences their site access strategy. Companies with smaller area of operations may allocate servicing jobs on the fly to their service personnel, companies with customers further away tend to visit the office first to ensure they have the necessary utilities with them prior to accessing the site.

Diagnosing phase

After arriving at the customer plant, the service technician seeks to isolate and diagnose the fault. The duration of this phase was determined in the survey by inquiring the average on-site duration of a service visit and the share of on-site time used to problem-diagnosing activities, problem-fixing activities and inquiring for additional information. Based on the answers, the average duration of the diagnosing phase was 45 minutes, corresponding to 36 percent of the average total service visit duration. On average 14 minutes (11 percent of the total service visit duration) of this time was used for acquiring additional information. The standard deviation for the duration of the diagnosing phase was 27 minutes.

In practice, there are several sources from where to look for information. First of all, there are three possible information sources on site. Some pieces of product information can be found from the product itself, e.g., information on the type of lubricant is attached to every new product manufactured. In addition, some documents such as electric diagrams are delivered with the product to the site of usage. The problem with these documents is, as the service technicians pointed out in the interviews, that they are seldom found at the user site when needed. The third source of on-site information is the paper documents stored in the service vehicle. However, due to the large number of different products serviced, it is not possible to carry all the required documentation in paper format. Due to these issues, service technicians need to inquire for information from outside the service site. Based on the survey, we determined that the service technicians most typically contact their own office, if information is missing. Also, each service technician contacts the focal manufacturing company on average 0.7 times a month to inquire for information. In total, this encumbers the case company's technical support staff with hundreds of technical inquiries a month that are due to the poor availability of information.

The value of equipment life-cycle information was examined in the survey with a multiple-choice question. The value of distinct items was estimated in terms of utility with the options of significant utility, moderate utility, minor utility, and no utility. The most valuable piece of life-cycle information was operating data (temperature, pressure) of the equipment (90 percent responded significant or moderate utility). Other data experienced useful were service history and spare parts installed (87 and 80 percent significant or moderate utility, respectively). The least important of the surveyed items was data on operating environment (53 percent responded significant or moderate utility).

Based on these answers, better availability of information would indeed improve the fault-diagnosing phase. Currently, the service technicians have to work with incomplete information on the serviced equipment, which reduces their efficiency to locate quickly and reliably the problem at hand.

Defect rectification

According to service technician interviews, defect rectification can involve cleaning, adjusting, repairing, or component changing activities. Based on the survey, this phase takes on average 1 hour 19 minutes corresponding to 64 percent of the average service visit duration. The service technicians commented that the duration of this phase varies a lot, and consequently the results showed rather big variance with a range of 27-240 minutes and a standard deviation of 42 minutes.

The defect rectification step can be argued to be the most important phase of the whole defect rectification process. The information needs during the rectification consist of product documentation on product structure, such as diagrams and settings. The availability of these documents and consequences of non-availability are discussed.

Service success ratio

If the defect cannot be rectified during the field-service visit, the costly downtime of the equipment continues until a new visit can be scheduled and completed successfully.

In this section we discuss the reasons behind failing service visits in this case in order to be able to quantify the problems caused by poor availability of information.

An overview of the average situation for a service company in a month is given in Figure 2. Based on the survey answers, the average service call success ratio for the service companies was 79 percent (success ratio, Figure 2). That means, on average, every fifth service case requires another visit to the site. Only for 17 percent of the survey respondents the success ratio was 70 percent or less. Based on this measure, the maintenance performance of the service companies is rather uniform.

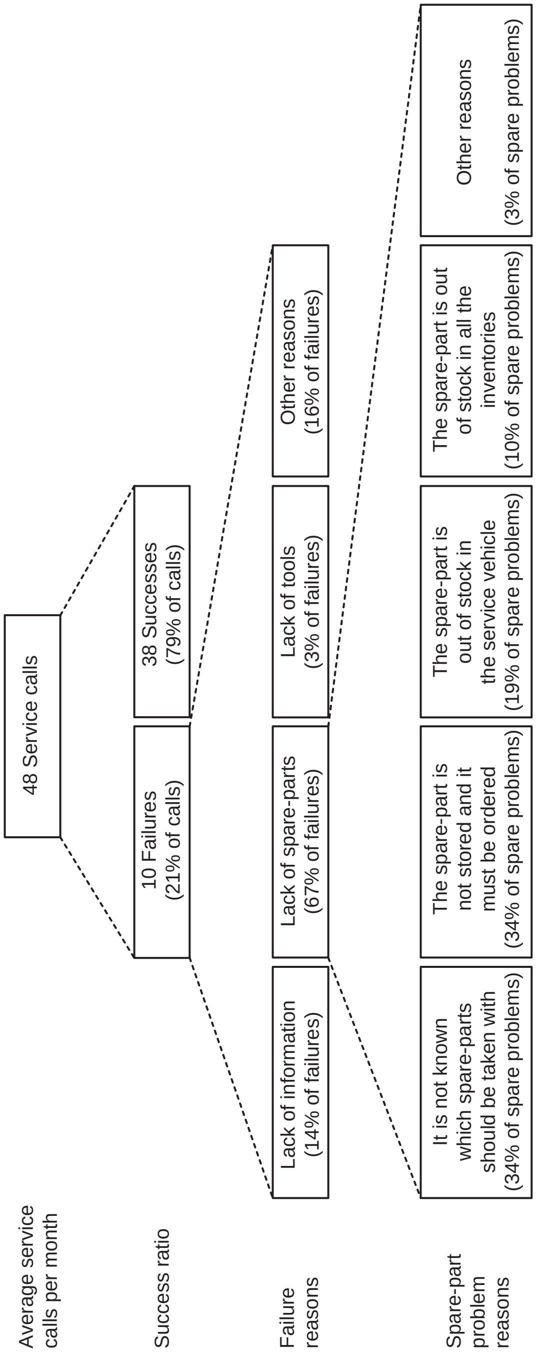
To assess the reliability of this result, the service call success ratio was determined based on the warranty service invoice data as well. The survey result received verification as the average success ratio for the services made during the warranty period was found to be 75 percent.

From customer perspective, the downtime continues in breakdown maintenance until the service technician returns for a follow-up service visit to rectify the defect. The time customers have to wait for the follow-up service visit was determined based on the warranty service invoice data. On average, it takes three days for a follow-up visit but the spread is quite large. For 19 percent of the cases it takes longer that a week and 19 percent of the follow-up visits can be accomplished during the same day. Therefore, for a customer a failed service visit means several days more of unplanned downtime that affects the customer's perception on the reliability of the manufacturer's products.

To find out why some service visits fail, the failure reasons and their significances (failure reason, see Figure 2) were inquired in the survey. The respondents had to estimate weights for the given failure reasons: lack of spare parts, lack of documents or information, and lack of tools. In addition, the respondents could fill in other failure reasons and their weights as well. It turned out that the main failure reason was the lack of spare parts, which caused two-thirds of failed service visits. Lack of information or documents was the reason behind 14 percent of the failed service visits while the lack of tools was the reason in only 3 percent of the cases. The last 16 percent was caused by other reasons, which were mainly customer-related reasons, such as the customer's contact person being unavailable at the time of visit.

There were several reasons why the service technicians may not have the needed spare parts while on site (spare-part problem reasons, see Figure 2). Therefore, the survey was used to determine what the relevant reasons in this particular case were. As a result, the two main reasons for missing spare parts was found to be that it was not known which parts should be taken along when leaving for service site, and that the spare part was not stored and it must be ordered. These both account for 34 percent of the cases when a spare part was missing. The next significant reasons were that the spare part is temporary lacking from the service vehicle, and that the spare part was out of stock. Other reasons account for the remaining 3 percent.

The service technicians have a need for a great deal of information when carrying out the on-site operations. In the examined case, the information was not always available due to the characteristics typical of most field-service organizations: paper-based documentation is poorly portable, and the amount of documentation is very large (Marsh and Finch, 1998). Based on the survey answers, the lack of information was the reason behind 14 percent of the failed service visits. In order to better understand this failure reason, the respondents were asked to specify the missing of which particular document or piece of information typically prevents from completing a service call. The most typically missing document was electric diagram,



Note: Responding companies average situation over one month period

Figure 2.
Service call success ratio and failure reasons

which was mentioned by 11 of the total 24 respondents to this question. According to the interviews, this document is delivered to the plant with the equipment, but the electricians often misplace it during the installation works and therefore it is missing when needed later.

One important factor that led to missing information was that documents were not available and the information was inadequate for the service companies' on-site needs. Service companies' preferences for the locations where different pieces of information should be available were inquired in the survey. When these results were compared to the current availability of documents, some rather large discrepancies in information's actual availability and required availability was recognized. For the most typically missing document, electric diagram, 80 percent of the respondents wanted it to be physically attached to the equipment.

Summary

To provide an answer for the first research question, "How does missing equipment information affect field-service delivery performance?" we examined the field-service delivery process of the case in the light of the framework for defect rectification process (Figure 1). The findings indicate that almost 40 percent of the failed service visits are either directly or indirectly caused by missing information. Missing document or piece of information is the reason of 14 percent of the failed service visits. With better availability of information on the service site, these failures could be eliminated.

However, the single most important reason for a service call failure is insufficient advance information on the spare parts that would be needed during the service visit. This was the reason behind 24 percent of the failed service visits. If the service technicians would have had advance information on the model of the equipment and possibly on the failure type, they could have been better prepared and have the proper spare parts when arriving on site the first time. Having all the possible spare parts in the service vehicle would not be possible due to the large variety of spares and due to the large size of the most frequently missing components. Therefore, the solution is better advance information that would allow more accurate preparation for the service calls. That way, the service technicians would also be able to prepare themselves with the required tools, the lack of which was the reason behind 3 percent of the failed service visits. These improvements in information availability would ultimately allow the service companies to accomplish 40 percent of the currently failing service calls, and thus increase the success ratio from 79 percent to around 87 percent.

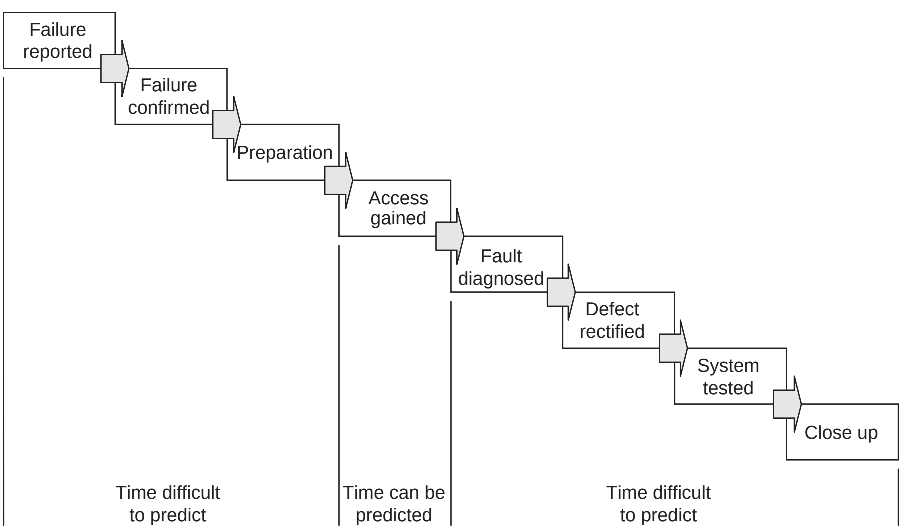
A second effect of missing information is that valuable on-site time has to be spent to acquire information from several sources. Currently 36 percent of on-site time is spent with problem diagnosing and searching for information. We conclude that the information unavailability in this case was caused by non-conformity of means requested and provided. Better data could help to reduce the problem diagnosing time, and better availability of information could help to reduce the information acquiring time. Therefore, proper tools to access or other arrangements to make relevant information available could cut down the duration of the on-site service operations.

The objective of the second research question was to find out, what are the most critical pieces of information required in the field-service delivery process. We argue that the biggest benefits could come from better preparation of the field-service delivery. There the most important piece of information is the identity or type of the equipment to be serviced. If the service technicians knew which equipment they will service, they could prepare better in terms of spare parts, documents, and tools. In addition, advance information on the type of the failure would make the preparation more efficient. To improve the on-site operations, manufacturer's product documentation should be better available. In this case, especially electric diagrams and settings for electronic components were typically missing documents. Thus, the lack of very basic information was a major reason for service delays, not necessarily the lack of sophisticated tools. When devising inventive tools for maintenance operations, it is important to understand the service technicians' actual information needs and fulfill them by the appropriate means.

Conclusion

Findings of a case study cannot be generalized, but viewed in combination with theory novel theoretical proposals can be made. Building on Knotts (1999) we propose that his framework for facility-based maintenance needs to be modified for the context of field-based maintenance. In field-service delivery the service personnel needs to ensure they have all the proper parts and tools for the task before the access-gaining phase. Our research results indicate that for field-based services the repair process framework presented in (Knotts, 1999) should be appended with a preparation phase (shown in Figure 3). Based on our research results, the effectiveness of the preparation phase has a major impact on the durations and success probabilities of the latter process phases. The effectiveness of preparations in turn depends heavily on the equipment information available at the time of problem detection.

When designing informational support tools for maintenance operations, it is important to understand which phases in the service process currently lack information and what the potential impact of better information could be. We have first, identified the relevant process phases and developed the framework presented by Knotts (1999) further to enable the analysis of information impacts on distinct process phases in field-based maintenance services, and second, demonstrated the



Source: Extension on model proposed by Knotts (1999)

Figure 3.
Preparation as a new component of defect rectification time in field-based maintenance

magnitude of impact on process performance that unavailable information may have in the context of one case.

The findings of this case study emphasize the distinct characteristic of field-based service: there is no centralized service production facility that can be optimized for field-service delivery (Auramo and Ala-Risku, 2005). Instead, the service personnel need to establish service production on site, making the preparation for the service call a process phase of crucial importance. Based on our findings, the single most important means to improve performance of field-service delivery is to ensure that the parts, tools, and documents needed on site are correctly identified during the preparation phase. The decisions that have the biggest impact on the service visit success ratio are made prior to accessing the service site.

Users, service companies, and original equipment manufacturers need to collaborate on availability of equipment information to improve performance in field-service delivery. Reducing the requirement for repeat or follow-up service calls is one of the largest cost-saving opportunities for companies engaged in field service (Brown, 2003) and the total improvement potential of better information availability can be considerable. From the customer's equipment performance viewpoint (Campbell, 1995), it would in the case setting be possible to significantly reduce the equipment downtime by making sure the service personnel appropriately prepared for the first service visit. This would also be in the interest of the service provider as it would have a huge effect on the service level experienced by the customer. From the service company's process and cost performance viewpoints, better information would also increase operational efficiency of field-service delivery, releasing capacity for more maintenance work and thus a potential for productivity lead growth and increased revenues. Even for original equipment manufacturers outsourcing service delivery the realization of the improvement potential would be important to increase both customer satisfaction and the company's brand image. After all, failed equipment carries the name of the manufacturer, not the service partner.

From the perspective of research, a fruitful direction is to develop the concept of integrity management (Kumar *et al.*, 2009), emphasizing the availability of information across organizational boundaries, and over time, in the context of field-service delivery of original equipment manufacturers and their service partners.

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