A Simulation Study: The Business Value of E-business for a Maintenance Provider

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ABSTRACT

The exploitation of IT using the Internet platform to integrate inter-firm processes, often termed "e-business", has gained research attention due to its potential to enhance the competitive position of businesses. However, the business value of new e-business technologies has remained unexamined given the complexity of the processes through which value is created. In this study we investigate the value of an emerging e-business technology, founded on mobile cloud computing technology. We focus on evaluating the prospective impacts of a collaborative manufacturing network, currently developed by an EC research project, in an automation maintenance company. Three simulation models were constructed, one for the traditional corrective maintenance operation mode as well as two alternative maintenance scenarios enabled by the collaborative platform that allows dynamic allocation of technicians, based on fault status. The results show that by using the collaborative platform, efficiency and service quality can be improved along with reduced cost and improved sustainability. Moreover, communication infrastructure quality negatively affected system contribution. Results also show that the collaborative capabilities, allowing effective handling of different demand volumes, have also improved system flexibly along the demand dimension. Managerial implications of the results are discussed.

INTRODUCTION

The new supply chain process capabilities enabled by Internet-based Information Technology (IT) have stimulated a shift toward digitized integration across supply chain processes that is gradually replacing the conventional processes between supply chain entities (Dong et al., 2009). This shift emphasizes the exploitation of IT using the Internet platform to integrate inter-firm processes, from upstream (supplier) to downstream (customer) operations (Lee, 2000). Often termed "e-business", Internet-based supply chain integration (Zhu, 2004) enables the sharing of accurate and timely information and the coordination of activities between business entities. Such e-business-based capabilities are expected to enhance the competitive position of businesses that successfully incorporate them (Rai et al., 2006). Much research, in both the information systems and operations research disciplines, has focused on the relationship between e-business technologies and organizational performance (Zhu and Kraemer, 2005). However, the value of e-business technologies remained an elusive concept due to contradictory results, attributed mainly to the inconsistent definitions of the main concepts and lack of consideration of the contingency effects of business conditions (Van der Vaart and van Donk, 2008; Zhang et al., 2011). In addition, current literature has primarily focused on retrospective and subjective perspectives, using mainly survey-based methods, leaving the value of new e-business technologies unexamined. One such type is Mobile Cloud Computing (MCC), which refers to the combination of cloud computing and mobile networks, enabling execution of rich mobile applications on a plethora of mobile devices. It has been defined as "a rich mobile computing technology that leverages unified elastic resources of varied clouds and network technologies toward unrestricted functionality, storage, and mobility to serve a multitude of mobile devices anywhere, anytime through the channel of Ethernet or Internet regardless of heterogeneous environments and platforms" (Sanaei et al., 2013). Similar to other emerging technologies, determining the business value of MCC is a challenging endeavor, given the complexity of the processes through which value is created (Fink, 2010).

In this study, we evaluate the prospective impacts of MCC technology in the context of supply chain process capabilities. Specifically, we refer to a collaborative manufacturing network, currently developed by an EC research project (ComVantage project), and designed to provide an Internet-based collaboration space, with a secure access control, shared by all relevant supply chain stakeholders. The ComVantage network is based on mobile apps that shall support users in fast decision making and problem solving, using information from different sources across the organisations that is provided and maintained via Linked Data (www.comvantage.eu). The network is intended to provide a secure inter-organisational collaboration space in various manufacturing environments that are

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represented in the research project through several use cases. The business value of the collaborative network for the manufacturers in the fashion industry was studied through the evaluation of the prospective network's implementation effects at an Internet-based fashion retailer (Raphaeli et al., 2013). The results indicated mixed performance impacts of upstream and downstream collaboration. While upstream collaboration facilitated improved efficiency but increased costs, downstream collaboration showed negative effects on both aspects.

This study refers to the maintenance industry, through a case study of an automation maintenance company specializing in maintenance of industrial machines. Maintenance of industrial machines is a complex and cost intensive task. It is concerned with providing immediate and efficient service by highly skilled and well trained service personnel. In order to increase its competitive advantage, the automation maintenance company aims at improving preparation of on-site maintenance operations through better identification and assessment of machine faults by introducing the ComVantage collaborative platform.

In the current study, we focus on examining the performance impacts of alternative corrective maintenance processes enabled by ComVantage capabilities to provide real time access to customers' machine data (downstream collaboration). Specifically, we investigate the performance impacts of both remote diagnosis and remote repair capabilities. Since machine data is sensitive, safety plays a major role in the implementation, thus access permission errors are expected. We thus additionally examine the influence of problems in attaining access permission on performance. We also consider the impact of demand characteristics on the process of value creation. The study aims to answer two key questions: (a) How does downstream collaboration affect operational performance? (b) Do demand characteristics influence this relationship?

CASE STUDY DESCRIPTION

iAutomation is an automation maintenance company, specializing in maintenance of industrial machines. iAutomation has 15 customers with either grinding (GM) or spinning (SM) machines. iAutomation employs three types of employees: Mobile Maintenance Coordinators (MMCo), Service Technicians (SvTn), and Machine Experts (ME). MMCos are in charge of communication and coordination of maintenance activities with customers and with SvTns. Each SvTn repairs either GM or SM machine according to his/her machine qualifications. SvTn are either shared or dedicated according to their assignment to customers. All SvTns operate from the main office and have a company car by which they drive to customer sites. They travel with all the required spare parts. MEs are also distinguished according to their machine qualifications (GM or SM). They operate from the main office, available for phone consultation.

The traditional corrective maintenance process, described in Figure 1A, starts with a customer's fault report handled by an MMCo, who opens a service request in the CRM system, verifying the customer's service level and recording report details. Then the MMCo assigns a SvTn to the task, based on distance from customer and SvTn load, and informs the SvTn of the fault's details by email or SMS. The assigned SvTn drives to the customer's site (if time constraint allows) and analyses the fault. In case of successful analysis, the SvTn repairs the machine. If the analysis is not successful, the SvTn calls the ME for consultation. The ME analyses the fault and guides the SvTn how to repair it. After the SvTn fixes the fault, he/she updates the MMCo by SMS/ email. The MMCo closes the service request in the CRM system and checks if an additional fault has been assigned to the SvTn. If an additional fault has been assigned, the SvTn starts treating it. If not, the SvTn drives back to the main office and waits there for additional assignments.

The collaborative platform facilitates access to machine data by the maintenance service company personnel using their mobile devices. The machine data accessed includes structure, maintenance records, and state. Machine state is represented by sensor readings, e.g., temperature and pressure. The mobile access to machine data and available diagnostic apps are expected to contribute to reduce maintenance visits (single visit per fault), reduce the time it takes to repair the machine, and improve fault identification by less skilled personnel. The collaborative capabilities enable an alternative maintenance process, in which SvTns and MEs have mobile access to the customer's machine data, can perform diagnostics tasks based on machine records and sensor readings, and can remotely adjust system parameters. In addition, faults can be dynamically allocated to SvTns and there is no need for a fixed assignment when the fault report is received.

The alternative process, enabled by the ComVantage collaborative platform, is described in Figure 1B. In this process flow, customer's fault details are updated by the MMCo in the Linked Data Store (LDS), which can be viewed by all SvTns. An available SvTn chooses the next assignment using a mobile app (based on an assignment algorithm recommendation). The SvTn starts performing a remote analysis from his/her current location. In cases of access denial (e.g., in case of no internet connection or insufficient permission privileges), the SvTn contacts the MMCo who solve the problem and the SvTn can continue with the analysis. In case of successful analysis and when remote repair is possible, the SvTn repairs the fault from the remote site and marks it as repaired in the LDS. When remote repair is not possible, the SvTn drives to the customer's site (if time constraint is satisfied) repairs the fault, marks it as repaired in the LDS, and continues to process service requests from the LDS. The MMCo finalizes the service request, marks it as repaired, and sends a message to the customer that the machine is working again. In case the problem cannot be solved by the SvTn, the fault is allocated to an ME who can use the test results, previously performed by the SvTn, for his/her analysis. Meanwhile, the SvTn continues processing additional requests from the LDS. The ME performs the repair, if remote repair is possible. If not, the service request waits for an available SvTn.

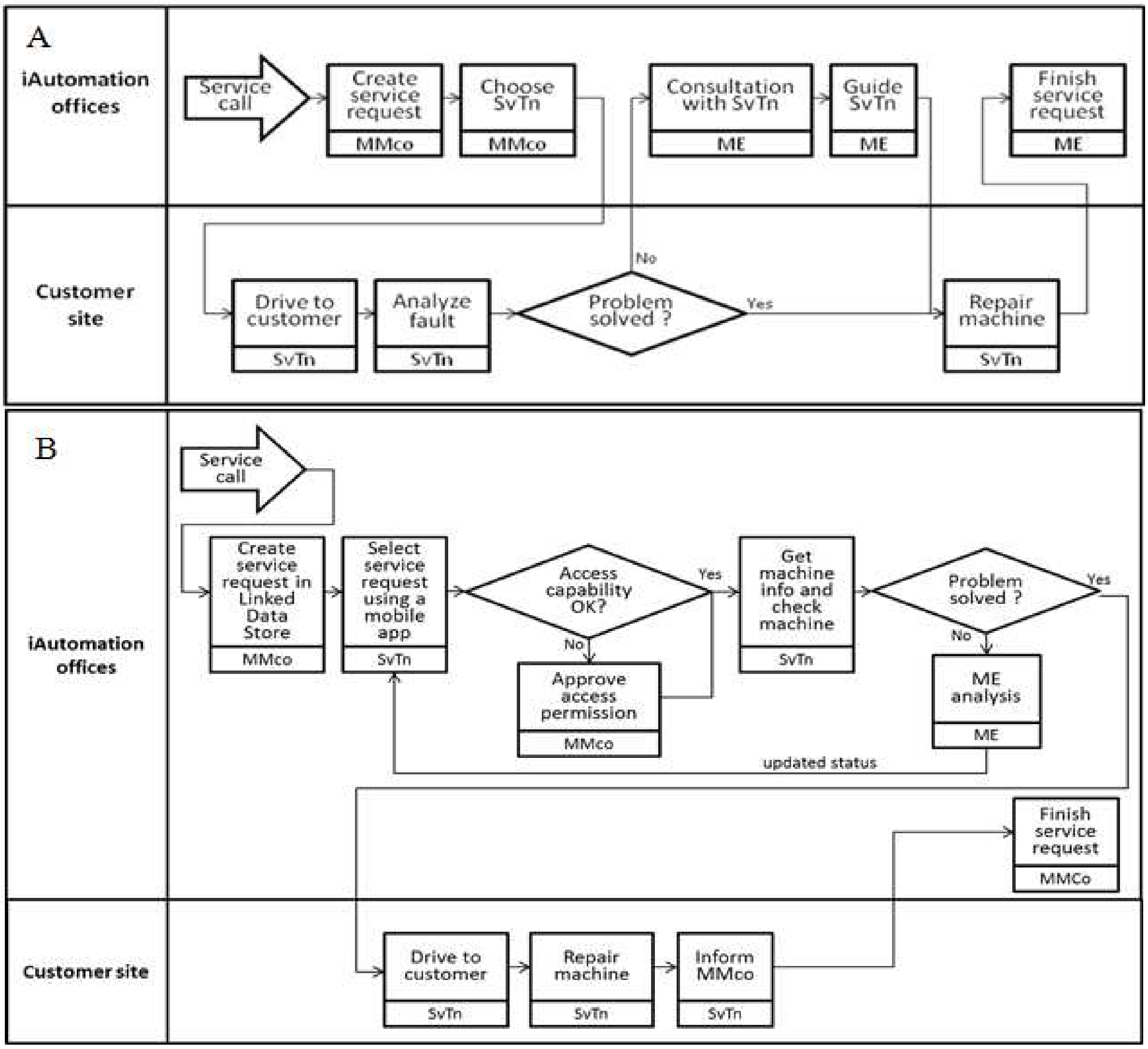

Figure 1: A) Traditional maintenance process flow, B) Collaborative maintainance process flow

SIMULATION MODELS

Model description

Simulation models, representing three process flow options, were programmed using ARENA simulation software (Rockwell Automation, USA). The "On-site Maintenance" (OM) model is for the traditional operation mode where maintenance is done only on-site and technicians are statically allocated to a fault. The other models refer to two maintenance scenarios of the ComVantage-enabled maintenance process. The "Mobile Maintenance" (MM) model is for the ComVantage enabled mobile maintenance scenario with dynamic SvTn allocation based on fault status. The "Mobile maintenance-Permission Error" (MM-PE) model additionally incorporates the possibility of errors in permission requests.

Two average fault arrival rates were tested: a Base arrival rate and a High arrival rate. The two fault arrival rates were determined according to Mean-Time-Between-Failures (MTBF) values of each fault.. Fault inter-arrival time is exponentially distributed.

The process in the three simulation models starts with the arrival of a new service call to the MMCo and ends once a machine is marked as repaired. In all models, machine faults occur weekdays Monday through Friday, 6:00AM to 10:00PM. During MMCo working hours, they are immediately reported. Faults that occur after MMCos working hours are reported the next morning between 8:00 and 9:00. Fault reports are treated by the MMCo sequentially according to their incoming time (full SLA have priority over partial SLA). Analysis and repair times are triangularly distributed with paprameters that vary according to fault specifics.

In the MM-PE model, 10% of the permission requests incur errors requiring assistance of the MMCo. Each model was run ten times with each rate (total of 60 simulation runs). Each simulation run lasted 4 years (48 months), where half a year (six months) was regarded as warm-up time.

Analysis

Several measures were used to evaluate the implications of ComVantage-based mobile maintenance capabilities and the implication of errors in permissions requests. Mean-Time-To-Repair (MTTR) is related to quality of service and to efficiency. Average Monthly travel distance (MTD) allows assessment of sustainability and cost performance aspects. Worker utilization (ME, SvTn, and MMCo) is related to efficiency.

The experiment was designed as a repeated measure analysis of variance (ANOVA) with policy (three levels: OM, MM, MM-PE) as the within-subject factor and fault arrival rate (two levels: Base, High) as the between-subject factor. The ANOVA was followed by a Bonferroni-corrected post-hoc analysis. The Common Random Numbers (CRN) variance reduction technique was applied inducing correlation between the three models facilitating the repeated measure analysis.

RESULTS

The schedule compliance (percentage of service calls that satisfy contract time commitment) of all models was above 98%, thus indeed all models represent valid organizational operational scenarios. All main effects and interaction tested were significant at $p<0.001$, except for ME utilization, for which the utilization did not differ between both mobile models (MM and MM-PE).

For both fault arrival rates, the mobile maintenance models (MM and MM-PE) had significantly lower MTTR than the OM model (Figure 2-Top). Indeed permission error increased MTTR in the MM-PE model relative to the MM model, yet this increase is much smaller than the difference between the MTTR for the MM and OM models. In addition, the difference between the MTTR for the different fault arrival rates in the mobile models is much smaller than in the OM case. The monthly travel distance (MTD) of the mobile maintenance models is lower than that of the OM model (Figure 2-Bottom). The MTD for the MM-PE model is smaller than for the MM case, due to additional time required for handling the permission errors the technicians, on average service less customers in each shift, thus they drive to less sites on a daily average. This is also is reflected in the prolonged MTTR in the MM-PE model relative to the MM model.

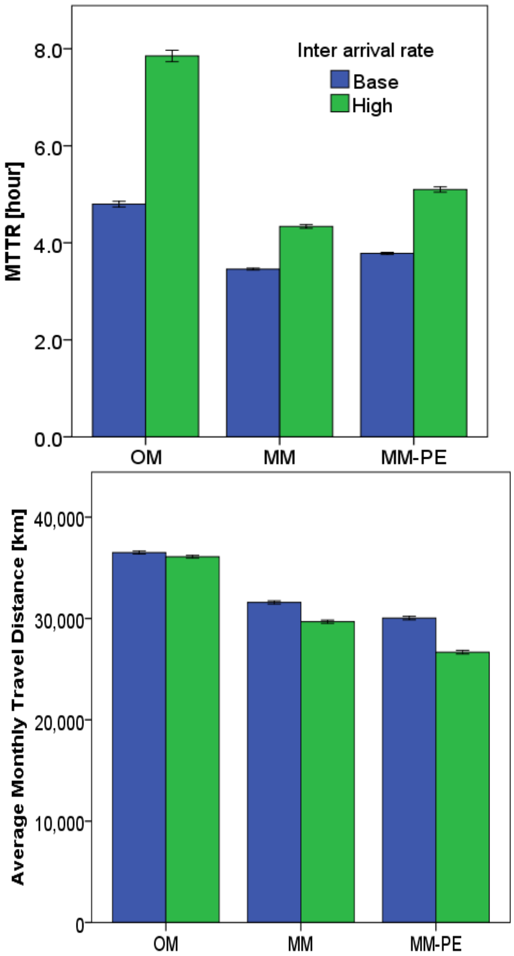

Figure 2: Top: Average monthly travel distance (MTD). Bottom: Mean time to repair (MTTR)

The MMCo utilization is similar in the different models, asserting that the collaborative system and handling permission error corrections do not overload MMCo operation (Figure 3). While average SvTn utilization in the MM model is lower than in the OM case, in the MM-PE model the SvTn utilization is the highest, which is a sign of concern regarding the effect of permission errors on SvTn workload. The utilization of the ME in both mobile models is lower than the utilization of the ME in the OM case. This asserts that not only was the ME not burdened by the collaborative system, but rather that his/her workload was reduced.

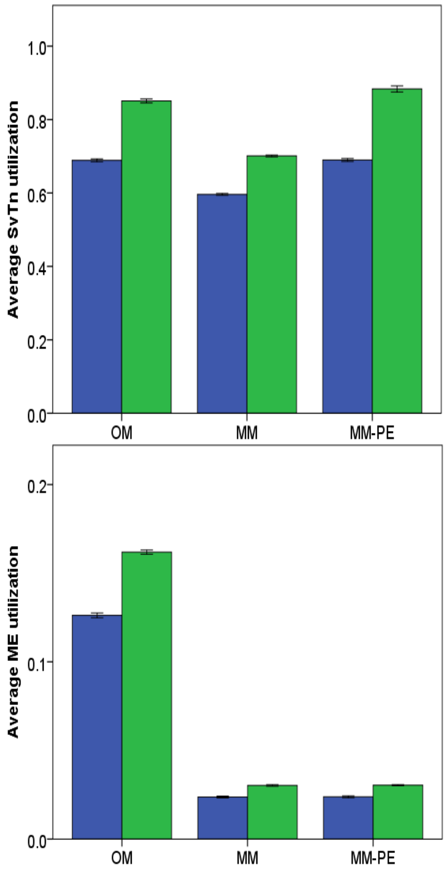

Figure 3: Top:SvTn utilization. Bottom: ME utilization

CONCLUSIONS

The results show that using the downstream capabilities provided by the collaborative platform improved the efficiency and service quality (MTTR and utilization), reduced cost, and improved sustainability (MTD). These findings are encouraging as they demonstrate a situation where improvement can be gained alongside a cost reduction. Permission errors are of concern as they negatively affect system contribution by reducing MTTR and adding to SvTn workload. This points out that investing in communication infrastructure (hardware and software) and reducing the rate of permission error events is of importance. Finally, the results show that while indeed demand volumes affect system operation, the collaborative capabilities improve system capability for effectively handling different demand volumes, improving system flexibly along the demand dimension.

This study employs the DES methodology for investigating performance impacts of emerging e-business technologies, during its development, using a process-oriented approach. Studying the impact of IT in specific business processes, at the same level at which IT is deployed, enables the research to transcend the correlational evidence between IT and business value. Therefore, this approach should complement, rather than substitute, the common, survey-based approaches. We suggest expanding the use of this approach to assess impacts in various organizational settings. It can also be used to support decision making about which e-business technologies are effective in specific organizational circumstances.

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