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Abstract: The rapid technical progress in the development of mobile devices and technologies offers new possibilities for improving and streamlining the performance of business processes. However, only few successful mobile applications exist in the business area. This paper discusses the benefits an enterprise can gain by using mobile technologies in business processes. It presents general indicators to measure the performance of business processes and shows how these indicators must be adapted to be useful to determine the benefit of mobile applications. Then, the set of indicators is applied in a real-world scenario. The results show that indicators like throughput time, error rate, reduction of redundancy, and increased flexibility are important for the benefit of mobile technologies.

1. Introduction

The rapid technical progress in the development of mobile devices and mobile technologies offers many new possibilities for improving and streamlining the performance of business processes [11]. Due to the widespread use of mobile devices, users can always be on-line, they can always be connected to central ERP systems, non-mobile business processes can easily be substituted or extended by mobile processes, and nearly each physical item can become part of a mobile application. As over the last years the network coverage increased to a high level, these possibilities can be realized location-independently and almost everywhere [21]. However, there are tight limitations for introducing mobile technologies in business processes. An important factor for using mobile technologies in business processes is choosing the right process. Appropriate processes must be adaptable to mobile technologies and must deliver a measurable benefit for both the user and the enterprise. Without measurable additional benefit due to the introduction of a mobile technology, an enterprise will not adopt mobile technology [2]. Therefore, one of the main challenges for using mobile technologies in business processes is to determine the potential benefit that results from the introduction of mobile technologies [22]. To create successful mobile applications, an enterprise has to carefully analyze a-priori for which processes which mobile technology can result in an overall higher benefit (profit).

The goal of this paper is to study the benefit that results from the use of mobile technologies in business processes. To be able to determine the potential benefit, in a first step we review existing performance indicators for business processes. Then, we examine which performance indicators are affected by the use of mobile technologies. Furthermore, we introduce additional performance indicators that take into account specific characteristics of processes supported by mobile technologies. Finally, we apply our indicators to a real-world business process in the area of a warehouse management and production system. This allows us to examine the impact of mobile technologies on business processes for one specific example (RFID tags) and to verify the benefit resulting

from the use of mobile technology. We do this by studying various scenarios and measuring the differences between scenarios with and without mobile technologies.

The paper is organized into six sections. Section 2 describes some indicators for measuring the performance of business processes. Section 3 summarizes specific properties of mobile technologies and Section 4 outlines how which indicators are appropriate to measure the quality of mobile business processes. In section 5, the performance indicators are used to determine the benefit of mobile technologies in a real-world case study.

2. Performance Measurement of Business Processes

This section summarizes indicators for measuring the performance of business processes and discusses methods for determining their performance.

2.1 Indicators for Measuring the Performance of Business Processes

To measure the performance of a business process it is necessary to determine some indicators which represent important aspects of the process and the way in which the process is performed. In general, performance indicators can either be classified as quantitative or qualitative [6]. Quantitative indicators usually measure performance by using ordinal numbers (or a rank order) whereas qualitative indicators do not allow a direct ranking or comparison of performance aspects [19]. Common quantitative indicators are

- time,
- costs,
- error rate,
- number of performed process steps, and
- stock size.

There are different possibilities for measuring duration times of business processes. It is possible to measure the duration of single process steps, the time between process steps (assuming that there are waiting times), or the overall execution time of a task. Furthermore, we can count the number of process steps that must be performed to execute the entire process. [8] sub-divides performance indicators in procedure-oriented and resource-oriented categories. Both categories can be split in different sub-categories. One sub-category addresses the time aspects. These are considered in the categories operation time, holding time, and down time (resource-oriented indicators) as well as in the categories cycle time, execution time, and queue time (procedure-oriented indicators).

Cost aspects are also important for determining the benefit of business processes. Examples for costs are processing costs or used capacity costs [8]. [6] argue that only time and costs aspects determine the benefit of a business process. However, there are additional indicators that are relevant for the performance of business processes like the error rate of the process. The error rate describes how many errors occur when the process is performed [18], [17]. Furthermore, it is possible to measure the process quality by counting the number of process steps that are either performed or not performed [8]. In combination with the error rate this indicator describes the robustness of the process. A process can be assumed to be robust if the process steps are correctly performed even if some errors occur. Finally, the size of the stock can be measured [16]. A lower stock size results in lower capital lockup what results in higher benefits for the enterprise.

Common qualitative indicators are

- process goals,
- stakeholder goals,
- enterprise goals,
- flexibility, and

- process quality.

Every business process is performed to reach specific goals. In general, the quality of a business process depends on the extent these goals are reached. However, there is no unique process goal but there are different goals for different stakeholders like employees, managers, investors, or the enterprise. To determine process quality, the goals of the different stakeholders must be considered [1]. Examples for different goals are that employees are not interested in additional monitoring and controlling steps as such steps increase their work load whereas managers are interested in additional process steps to ensure a lower number of errors while performing the process. Furthermore, the goals of employees or managers do not necessarily correspond to the goals of the enterprise [19], [1]. For determining process performance, it must be measured to which extend the different goals are fulfilled. Another important qualitative performance indicator is the flexibility of the process. Flexibility measures the possibility to change the order of the process steps, to interrupt current processes, or to insert other processes without loosing data or without additional cost [12], [13]. Finally, the quality of the process is important for the benefit of the business process [3]. The quality of a business process summarizes the previous indicators and describes how well these are fulfilled. If a process coincides with the different goals and if it is flexible, it is performed well by the employees with high probability and the enterprise can gain some benefit from this process. Therefore, the quality of the process is a precondition to gain benefit from a business process.

2.2 On the Use of Performance Indicators for Determining the Performance of Business Processes

When using the performance indicators discussed in Section 2.1, additional factors must be considered for measuring the performance of business processes.

First of all, the environment of the business process whose performance should be measured by the performance indicators must be considered. This means, it is important which tasks should be solved by the process and in which line of business the process takes place [20]. In addition, the specific business area of the process is relevant [1]. To consider the task, the line of business, and the business area are important because these different factors influence the performance of a business process.

After this step, it is important to identify possible interdependencies between the different indicators. This is necessary to evaluate the impact of changes of a business process on other indicators and the corresponding process properties. Furthermore, some indicators can be based on other indicators [1] what allows an enterprise to get better information about the performance of the business process or to make a potential benefit visible. However, this also leads to interdependencies between the different indicators.

After defining the indicators that should be used for measuring process performance, it is necessary to determine in which intervals the indicators should be measured and who is responsible for the measurement and the management of the information/data [23]. For the analysis of the gathered data it is also necessary to determine target values that should be met [8]. Another option is to combine the measured values with values that are obtained in previous time periods to get more meaningful results [4].

Finally, the values of the indicators must be compared to target values or to results from previous periods. Using results from previous periods allows us to judge changes in the quality and benefit of a business process in comparison to previous periods. [8] emphasizes that the use of diagrams can be helpful for comparing the values of actual indicators to target values or previous values.

3. Using Mobile Technologies in Business Processes

This section describes aspects that are important when using mobile technologies in business processes. These aspects influence the benefit of business processes that are supported by mobile technologies.

Despite the hype of mobile technologies a few years ago, there is no significant number of business processes that are supported by mobile technology. There are many reasons for this "non-use" of mobile technologies in business processes. First, managers who decide whether a mobile technology should be introduced have no concepts and tools to determine the benefit they would gain from introducing such a new technology. Therefore, the decisions are often based on fuzzy perceptions and personal opinions of managers. Furthermore, the benefit of a business processes is often only measured at the end of the project, for example after a new technology has been implemented. This is too late and it would be more useful to determine the possible benefit of a mobile technology before the introduction of the new technology. This would give managers the possibility to change their strategy and the way in which the technology is introduced. Additionally, a-priori studies would allow designing new business processes that use mobile technologies such that they have maximum benefit for the enterprise.

The following aspects must be considered before introducing mobile technologies in business processes. For successful mobile applications it is important

- to choose an appropriate process,
- to choose a technology that fits well to the process,
- to consider specific properties of the resulting mobile application, and
- to ensure a proper fit between the used mobile technology and the end-user.

We will discuss these aspects briefly in the following paragraphs. First of all, not all business processes can be supported by mobile technologies in a reasonable way. It must be possible to design business processes such that mobile technologies can be used and using mobile technologies generates a measurable benefit for the enterprise and the users, respectively [2], [3].

The used mobile technology must be carefully chosen. Mobile devices differ in many aspects like size of the display, input of data, available interfaces, network connections, storage possibilities, or the processing and transmitting of data. When selecting an appropriate technology, the situation in which the technology is used must be considered. For example, in noisy environments the use of display to show data should be preferred in comparison to presenting information using acoustic signals.

It is important to consider specific properties of the resulting mobile application if the technology should be used by users that are inexperienced with technology. In many possible scenarios, end-users have not used mobile technologies (of even computers) before to solve their tasks. This means, that end-users only have limited skills in using mobile technologies and the resulting applications. To overcome such problems applications must be self-explanatory, easy to understand, and easy to use. Furthermore, to be fault-tolerant and to consider end-users with low experience of mobile technologies, the mobile application must be robust with respect to wrong usage [15] and it must restrict the way the end-user can use the application.

Finally, a proper fit between mobile technology and end-user is important. This means, not only the fit between task and mobile technology/application must be high but also the technology must be chosen in such a way that users who have no experiences in using technologies (e.g. plumbers) are able to use the mobile application/technology. To ensure the success of a new (mobile) technology, the way in which the new technology is introduced is important. Lacking skills of end-users can be alleviated by training and by offering support and help-desks [14].

We can summarize that when using mobile technologies in business processes it is necessary to choose the right processes, to use the appropriate technologies, to have a high fit between technology and user and between task and user. To address problems of inexperienced end-users, the introduction of the new technologies should be combined with trainings and additional support like help-desks.

4. Impact of Mobile Technologies on the Performance of Business Processes

This section describes how the use of mobile technologies can influence the performance and benefit of business processes.

Indicators that are used for judging the benefit of using mobile technologies in business processes should be applicable to non-mobile variants of the process as well as to mobile-supported variants of the process. Only then, we are able to compare the benefit of business processes before and after the introduction of mobile technologies.

If necessary and if the existing indicators are insufficient, new indicators must be introduced to consider the characteristics of mobile applications and mobile technologies [10]. Important indicators for studying the benefit and performance of business processes that use mobile technologies are

- throughput time,
- automation of work steps,
- error rate,
- access to information,
- flexibility,
- connection to the backend-system,
- robustness, and
- costs.

On of the most important indicators for the benefit of mobile technologies is the change of the throughput time. The throughput time is influenced by most of the other indicators and is usually one of the main reasons for introducing mobile technology in business processes. Due to the automation of work steps (e.g. when RFID is used to gather data) the throughput time can be reduced because less process steps have to be performed or previously manual process steps are performed autonomously. This often also leads to a reduction of (manual) work steps by using mobile technologies. For example, in many mobile applications the manual gathering of data and the input into the backend-system can be done autonomously.

As a result of higher automation of process steps the error rate of business processes is often reduced. Media breaks are avoided what leads to a lower error rate. Also the design of the mobile application has an influence on the error rate. Therefore, processes that are supported by mobile technology must be designed such that the input of data is fault tolerant and that the process and the technology restrict the way in which the data input is performed by the end-user.

The use of mobile technologies in business processes also changes the access to information for the end-user. Usually, by using mobile applications and/or technologies more or better information is available anywhere and anytime. It is important to measure in which way the better access to information affects the benefit of the business process. Furthermore, the presentation and usage of information can consider the current situation of the user as applications can be context-sensitive [7].

A side effect of better access to information is an increase of flexibility. This means, users can react more flexible to new situations because they have ad-hoc access to additional information. Furthermore, users or business processes can reduce waiting times

or use waiting times more effectively if they have easy access to additional information anywhere and anytime.

As mobile applications can be used anywhere, the connectivity to the backend-system is relevant. To have a permanent connectivity to the backend-system or to make periodical updates are important aspects in changing environments for always having relevant data available on the mobile client. Furthermore, the quality and bandwidth of the connectivity are important for the benefit of the mobile application. A low quality of the connectivity can dramatically reduce the benefit of business processes supported by mobile technology.

Using mobile technologies can have a large impact on the robustness of processes. On the one hand, robustness can be increased due to the better access to information, on the other hand, robustness can be decreased as performing tasks depends on the availability of mobile technology. Business processes can not be performed any more if there are problems with the used technology. There is a wide range of problems from insufficient battery power, no permanent access to back-end systems, up to problems with the software or operating system. For example, the substitution of paper by mobile clients can be problematic if the reliability of the mobile clients is low. In contrast to mobile applications paper is permanent, it can not crash, and it is fault-tolerant.

When judging the impact of mobile technologies on business processes, the costs associated with the introduction of mobile technologies must be considered. Costs occur as a result of changing existing business processes, acquiring mobile technology, integrating mobile technologies into the business processes, training the end-user, installing help-desks, and maintaining the mobile applications. The resulting costs are important for the overall benefit of using mobile technologies in business processes.

5. Case Study

We studied the benefit of using mobile technologies in business processes for a real-word scenario. The study took place in the field of a warehouse management and production system in an enterprise for medical technology in Switzerland. The enterprise introduced a mobile technology and we have been able to study the quality of the business processes before and after the introduction of the mobile technology. In detail, a business process with manual data-input done by the employees was substituted by a business process which collects data automatically by using RFID tags. This data collection is done when storing material and products and also when producing new products. In the production process, information is collected about what type of product is produced by which producer and which material and machines are used to perform which process step.

We performed the study in different steps. First, we analyzed both the original business process and the planned, mobile-supported, process based on the documents we had received from the enterprise which was responsible for implementing the mobile business process. In the next step, we identified the goals that should be reached in the original and in the mobile-supported business process. Based on these results, we chose appropriate performance indicators with respect to the used mobile technology (RFID). Then, we studied the workflow before and after the introduction of the mobile technology. We focused on error rate, flexibility, and throughput time. For measuring the flexibility of the process, we determined how often process steps became exceptional and could not be handled based on regular process steps. In addition, we compared the process steps performed in reality with the theoretical, a-priori, description of the new process. Finally, we identified the employees' perception of the goals of the business process, their intention to use the new technology, and their personal experiences.

In our study, we used existing technical documents, performed various interviews, and monitored the processes on-site. In the first step, after surveying the processes documentation, we adapted our system of performance indicators such that they fit well to

the process. The performance indicators measured the impact of the mobile technology on the efficiency of the stocking process, the error rates, the process flexibility, the number of work steps an employee has to perform when checking in or out new goods, the necessary time, and the overall profit the enterprise can expect from introducing the new technology. In the next step we made some interviews. We interviewed the project leader of the medical enterprise as well as some employees. The project leader was asked about the goals the enterprise wants to reach with the adoption of the new mobile application and about the trigger for introducing the new technology. The most important goal for the enterprise is to have better information available about the production process. (There are some rules in medical technology production which made it necessary to document the production process in detail and store the data for ten years.) With the use of RFID tags, collecting and storing of data should be done faster and with fewer mistakes. Another point is the controlling of the stock (random storage). This means they want to have better and faster information (quantity and place) about the products in stock. Furthermore, the integration of the new application in the existing ERP-System should lead to fewer problems and higher performance. Another important aspect is that they want to reduce the number of mistakes that persons make when inputting data. This is important because the details of the production process must be traceable for ten years. The trigger for introducing a mobile technology was that the management searched for a way to reach these goals. The employees were asked about their expectations and fears related to the introduction of the new technology/process.

We observed the following results: First, the automatic data input increases the efficiency of the business process as the error-rates and the throughput times are lower. Furthermore, the employees are satisfied with the use of the new technology as redundant data input has been eliminated and some of the input tasks are now done automatically. Problems occurred as some of the employees who worked with the original process for many years have been afraid that the new technology allows the enterprise to monitor the employees to a higher extend because every detail of the production process is documented. This fear could be reduced by the management by confirming that the data will not be used for monitoring purposes and by making obvious that the detailed documentation of the processes is due to public law (documentation duty) and to increase the quality of the product. Interestingly, the realization of cost savings has not been an important goal for the management when introducing the mobile application. The main goals are a higher quality of the documentation and an improvement of the quality of the products due to the use of RFID. Both goals have been reached by reducing media breaks.

6. Conclusions

This paper studied indicators that are able to describe the benefit of using mobile technologies in business processes. First, we gave a short survey about general indicators for measuring business process performance. The next step was to analyse which aspects are important when using mobile technologies in business processes. Furthermore, we described specifics of mobile technologies and their effects on the benefits of business processes. Finally, we performed a case study in a real-world scenario. The results showed that using mobile technologies reduced error rate and throughput time. Crucial for using mobile technologies in business processes was a high fit between end-user and technology which could be reached by designing the mobile applications user-friendly and by offering additional support.

Our further research will deal with analysing the benefit of using mobile technologies in business processes where the process structure and/or the used mobile technologies are changing. [5] studied the effect of changing the process structure without changing the technology and changing the technology without changing the process structure. They

found that both alternatives result in a better performance but combining both alternatives can lead to larger benefit. Furthermore, there is a higher potential for the use of mobile technologies. For applications that use real-time data or handle time-critical processes the benefit of using a mobile technology can be greater than illustrated in this study. In our future research, we analyse in which way these observations hold for other mobile applications and processes and which processes properties are important to deliver a high benefit by the use of mobile technologies.

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