Model for the Benefit Analysis of ICT

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ABSTRACT

The ratio between success and failure in ICT projects suggests a need for improved understanding of the ICT implementations. New methods to evaluate the ICT projects are sought. While process modeling has been under way in organizations for decades, this paper presents a new approach to analyzing benefits based on the introduction of ICT services. In our approach the success of ICT projects is evaluated by analyzing the productivity benefits they enable in the business processes of the users. In its novel way, this paper points out the significant role of interacting processes and related actors. With the help of the Three Viewpoint Model (3VPM) and skill-matrix approaches the critical factors related to improvement benefits can be found. Our tool allows analyzing and evaluating the output at the time even when the ICT project is not completed, also taking into account the dynamic nature of processes.

Keywords

Productivity, ict system, business process, process modeling, process improvement, critical factors, 3vpm, skill matrix.

INTRODUCTION

Turning investments in information and communication technology (ICT) into higher productivity is not trivial, but typically requires complementary investments and changes, such as new business processes, new skills and new organizational and industry structures (Brynjolfsson and Hitt, 2000). As a response to the evolutionary challenges, organizations have faced a need to implement business process change (Harkness et al., 1996; Kettinger et al., 1997). Prior research has witnessed that technological change always catalyzes organizational change (El Sawy et al., 1999; Halonen, 2004; Melville et al., 2004; Rummler and Brache, 1995) even if information technology (IT) alone is an insufficient factor in achieving business process redesign (Stoddard and Jarvenpaa, 1995). On the contrary, the failure rate of IS projects is generally known to be high (Gunasekaran et al., 2006; Schmidt et al., 2001).

The business process literature has contributed to IT benefit measurement and management in four major areas: Performance improvements, the issue of ISs reach tangible and intangible benefits and benefit evolution (Rummler and Brache, 1995). The challenges to improve business process are independent from the line of industry.

The correlation of the ICT system success to business process benefits is new and missing in the previous literature (Urbach et al., 2009). In the research, there is a gap between the ICT system features and the optimal business process change, which we try to fill. In the business process studies there have been three problematic areas that have limited their use in practical productivity research in organizations:

1.   Many business process improvements in practice are structural. The activities, resources or their relations in the process change with the improvements. Hence the effects of the improvements should be analyzed with methodologies that allow structural changes in process models.

2.   The processes interact with each other. The improvements in a process cannot always be studied without considering the effects in the related processes.

3.   There is joint use of resources or personnel in several processes in an organization. Hence, the improvement in one process has externality effects to other processes via these joint resources in the organization under study.

Furthermore, in the case studies where our model has been applied, a fourth problematic area also emerged:

4.   An operating real business process does not always behave according to the existing formal process specification used in the organization. These non-documented features of the real process may be essential to the potential process improvement development.

In this paper, we introduce our Three Viewpoint Model (3VPM) that has been developed to overcome these four problematic areas when analyzing process changes enabled by ICT. Our multidisciplinary approach takes into account interacting business processes and their improvements by studying how the IS changes the processes with respect to three different viewpoints, namely logical process diagrams, performance and cost. We utilize factor modeling when we describe and analyze the business we seek to influence. In this study, we also apply recursive interaction as we utilize research context originally from Reijers (2003).

BACKGROUND

Organizations need business processes because the business plan and strategy are implemented with them (Earl et al., 1995). Besides formal business processes, organizations need to utilize their informal business processes (Harkness et al., 1996; Renzi et al., 2009). To improve their business, organizations initiate change projects that seek for better productivity, service and quality (Lee and Ahn, 2008; Melão and Pidd, 2000). Typically, the change projects involve additional IT (Back et al., 2000).

The productivity increase results from ICT in industries and in the society are of rather recent origin (Brynjolfsson and Hitt, 2000). The productivity benefits of ICT investments are related to simultaneous organizational and process changes (Maliranta and Rouvinen, 2006) and to simultaneous HRM and product and quality related practices (Gera and Gu, 2004).

However, the level of investments and the associated risks involved in planning and implementing ICT require improved understanding of the ICT implementation process (Gunasekaran et al., 2006). In case of failure, the implementation may have a significant impact on organizational competitiveness. Gunasekaran et al. (2006) propose a framework to evaluate investments in IT/IS projects. The framework consists of General IT/IS evaluation and justification concepts; Evaluation criteria emphasized for justifying IT/IS projects; Techniques and tools used for evaluating and justifying IT/IS projects; and Evaluation of the implementation of IT/IS projects.

First approaches of business process development were published in the early 1990's (Davenport, 1993; Hammer and Champy, 1993). Business process was defined by Davenport (1998) as a specific ordering of work activities across time and place, with a beginning and end, and with clearly defined inputs and outputs. Davenport (1993) described process management as a lens of analysis through which notable benefits in business performance could be gained. The terms business process re-engineering (BPR) and re-engineering the corporation were also introduced at that time (Hammer and Champy, 1993). Stoddard and Jarvenpaa (1995) use a concept of business process redesign (BPR) and claim that BPR does not necessarily result in radical change in a short period of time. Harkness et al. (1996) emphasize the need for a process vision to integrate improvement work and provide a basis of planning. The management and improvement of business processes has after that generated a large amount of literature, including topics Process Innovation (Davenport, 1998), Improving Performance (Choenni et al., 2003), Workflow Management (van der Aalst, 1998) and Business Process Change (Harmon, 2003). All approaches have the same notion of improving the performance of the organization by developing the business processes.

However, before a process can be presented in any model, the relationships between the process and its parameters such as personnel, equipment, material, methods, tasks and technology should be understood (Emiris et al., 2001). The first task in business process development is the process modeling, where the necessary features of the process are documented. For example, questions to be responded concern order of tasks, available resources and duration of tasks (Back and Bell, 1995).

Back et al. (2000) propose activity-based costing as a tool for process improvement evaluations. In this tool, the cost for any given process is determined by examining the individual activities or tasks that comprise the process and after that, the costs are assigned to each task. Their technique is applicable across a wide number of disciplines including also administrative processes.

RESEARCH PATH

Our research was based on instrumental case studies (Stake, 2000) including 30 cases, of which part have been published (e.g. Alasalmi and Martikainen, 2008; Kuroda et al., 2009; Martikainen et al., 2010; Takemura et al., 2008). To find out and to analyze interacting business processes and their improvements we utilized multidisciplinary research methods (Onwuegbuzie and Leech, 2005). Sarker and Lee (2002) suggest an approach that gives equal consideration to social dimensions and the interactions between the social and the technological. Following that, we studied how the IS changes the

processes with respect to three different viewpoints, namely logical process diagrams, performance and cost. We have correlated process quality measures, such as quality of service or quality of work, to calculated performance measures including service and waiting times, task throughputs and resource utilization rates. The 3VPM approach has been interactively developed and verified with the case studies mentioned above.

In the example of this study we also applied recursive interaction as we utilized research context described in prior literature (Reijers, 2003). Contrary to our earlier case studies, the skill matrices were not built due to the available research material. While Kettinger et al. (1997) propose a stage-activity framework for business process reengineering with six stages, our approach verges on the topic from three angles. In addition, we utilized mathematical factor models to describe the interrelations between process performance variables and cost variables.

THREE VIEWPOINT MODEL

One of the fundamental principles is presented in Figure 1. The figure shows a simple service system and the co-creation of value of the service provider and the customer. When a new ICT service is provided, the interaction with the new service process changes the customer process in a way that creates the benefits (Martikainen, 2007). Generally, the new benefits obtained by the customer should be more valuable than the cost increase from the new service. In public services also the social benefits created by the service externalities have to be calculated (Figure 1).

Figure 1. The Benefits Created by a Service
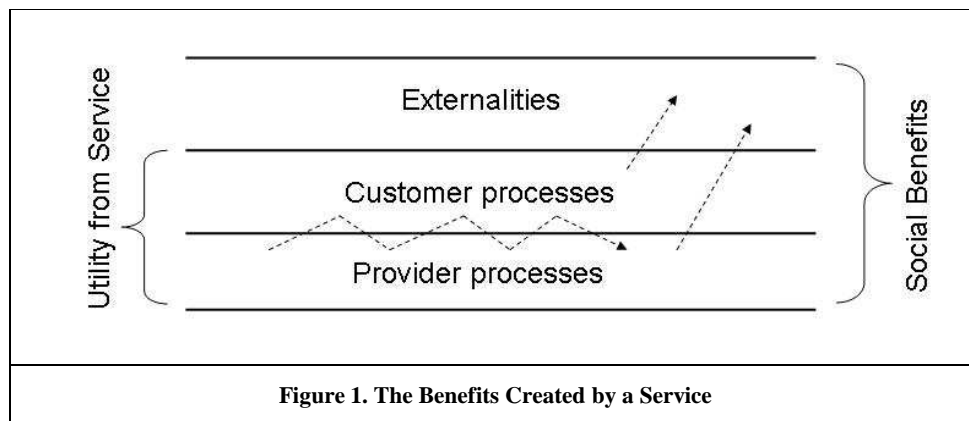
When evaluating the process changes enabled by an ICT service the 3VPM approach has four steps (Figure 2): 1. Draw diagrams, 2. Calibrate with data, 3. Draw improved diagrams and 4. Calculate improvement benefits. These steps are used in many business process improvement approaches. Our research target has been to develop the benefit calculations so that the proposed improvements can be evaluated with respect to the different viewpoints and the productivity gains calculated. A useful feature of the benefit calculation tool is also to show critical factors of the processes and to propose potential improvements.

Draw Diagrams

The first step is to draw logical process diagrams in order to describe the workflow in phases. This is done together with the employees using semi-structured interviews with the aim to produce a cognitive description of the work processes. Several descriptive models and graphical editors are available for documenting the step. In our analysis we applied the activity diagram notation based on the OMG Unified Modeling Language (UML) with extensions. In the case of services this approach necessitates that both the service processes and the corresponding customer processes are modeled. The produced process diagrams specify the logical process model denoted by M that caters process structure and variables that are described by activities, task classes, service times in activities, task routing probabilities between activities, resource costs in time and other activity costs (see Formula 1).
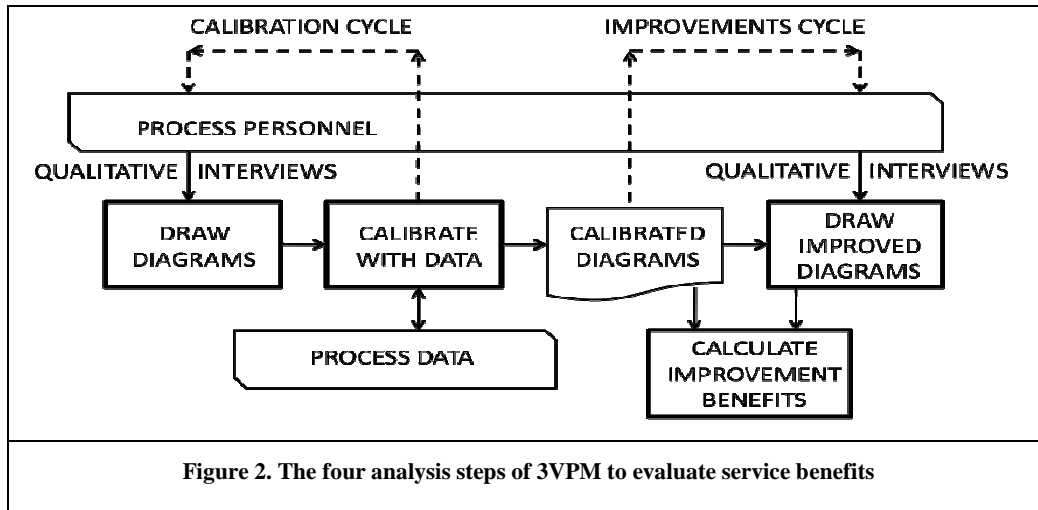
Figure 2. The four analysis steps of 3VPM to evaluate service benefits

Calibrate with Data

The second step was to analyze the process performance (see Formula 2) and costs (Formula 3). The variables used in 3VPM are activities (A_i), related resources (R_k), tasks and customers (E) served, task arrival intensities (λ_i) to the system, routing probabilities (π_{ij}) of tasks between activities, service times in activities (T_i), population sizes (N_i) and costs of resources (C_{Rk}). The performance related output variables are calculated from input variables using a queuing network solution for model M denoted by G (Denning and Busen 1978) and the cost analysis solution using a function denoted by F. The input and output variables are displayed in Table 1. Formulas 1, 2 and 3 define their interrelations.

Inputs		Outputs	
Activities or tasks	A_i	Customer time in activity i	W_i
Customer classes	E_p	Customers of type p in system	N_p
Routing probabilities	π_{ij}	Customers of type p in activity i	N_{pi}
Service time in activity i	T_i	Utilization of activity i	ρ_i
Arrival of customers p in activity i	λ_{pi0}	Utilization of resource k in activity i	ρ_{ki}
Resources	R_k	Throughput of customers p in activity i	λ_{pi}
Skills s in resource k	R_{ks}	Fixed costs	C_F
Time of resource k in activity i	R_{ki}	Variable costs	C_V
Resource k cost in time	C_{Rk}		
Activity i other costs	C_{Aj}		

Table 1. Input and Output Variables of an open 3VPM

$$M = (A_i, E_p, \pi_{ij}, T_i, R_k, C_{Rk}, C_{Aj}) \qquad\qquad (1)$$

$$(\lambda_{pi}, \rho_i, \rho_{ki}, W_i, N_p, N_{pi},) = G(\lambda_{pi0}, R_{ki}, M) \text{ and } R_k \geq \Sigma_i R_{ki} \qquad (2)$$

$$(C_F, C_V) = F(\rho_i, \rho_{ki}, W_i, M) \qquad\qquad (3)$$

The model M includes the process components and the variables of the calibrated diagrams. The function G is the solution of the open or closed queuing network representing the process. If M is an open model, which means that customers arrive

from outside, the variables and solutions are as given above. If M is a closed model, which means that customers circulate inside the system, the variable N becomes an input variable and variable λ_i an output variable. Usually G is an algorithm that cannot be given in a closed form. The function F simply calculates the costs based on the resource utilizations and customer delays that are obtained from G. In Table 1 the variables are given in the case, where the model M is an open queuing network, If M is modeled as a closed queuing network, then the variables N_p are considered as inputs and variables λ_i as outputs.

Solving function G for the model M and the variables λ_{pi0}, R_{ki} in Formula (2) does the performance analysis. In the skill matrix (R_{ks}, R_{ki}) the employees are classified according to their professions and assigned to the activities they are capable of working. Based on the skill matrix the optimal resource distribution over the processes can be calculated. The skill matrix calculation reveals for example the total quantity of each group of professionals per profession that can be optimally assigned to each activity. The skill and resource distribution of the original and improved process models can now be compared and the improvements in resource utilization levels analyzed. The joint use of resources that is specified in the skill matrix and the optimization algorithm included enables the analysis of externalities caused by resource sharing. For instance, an improvement in one process releases resources that can be moved to other processes in the organization.

In the cost analysis the fixed costs (C_F) in the processes are related to the costs of the fixed resources as well as to the fixed quality costs and fixed risk costs. The variable costs (C_V) of the processes are related to the product of the utilization and the cost per time unit of the variable resources involved as well as to the waiting costs, quality costs and risk costs that depend on the load of the system. In Formula 3 and in the corresponding input variables we have left out explicit quality and waiting costs for simplicity. The cost function F divided by the number of service transactions and calculated as a function of load represents the average variable cost curve generated by the production function of the system. The performance and cost calculation algorithms of formulas (2) and (3) are implemented as software in 3VPM analysis tools.

When the processes are analyzed using model M and functions G and F, the modeling results can be calibrated with the process performance data of the real process. The calibration means the comparison of existing real process performance statistics to the corresponding results given by the 3VPM analysis tools. If the calibration does not succeed iterative interviews are needed to correct the process diagrams and their variables. This creates more insight of the process behavior. This is the calibration cycle (Figure 2). Only after successful calibration the possible process changes can be modeled and their effects analyzed.

Draw Improved Diagrams and Calculate Improvement Benefits

After the original calibrated process diagrams have been created, new process diagrams enabled by the ICT service can be sketched. The improved diagrams are drawn as before using qualitative interviews where the possible improvements enabled by the ICT system are analyzed. This procedure is called the improvements cycle (Figure 2). For each improved model M_i the function G_i is solved according to formula (2) and the corresponding performance measures are calculated. The obtained performance measures of the improved models are then compared with the original ones and the possible improvement benefits can be calculated.
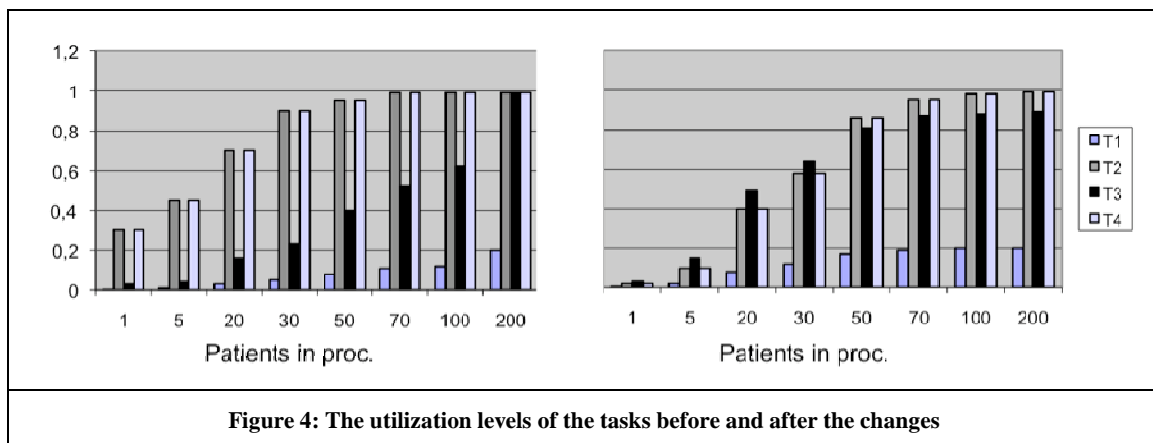
EXAMPLE

Our service process improvement example "Intake to Mental Care" is originally from Reijers (2003) and its possible improvements are analyzed using 3VPM. The model is divided into customer and service processes, which interact (Figure 3).

A customer enters the service and patient data is recorded by secretary (task T1 in Figure 3). Then customer waits while the case is treated in the team meeting next Wednesday. In the team meeting the intake psychologist and doctor who interview the patient are decided (task T2).

**Figure 3: The customer and service processes of "Intake to Mental Care"**
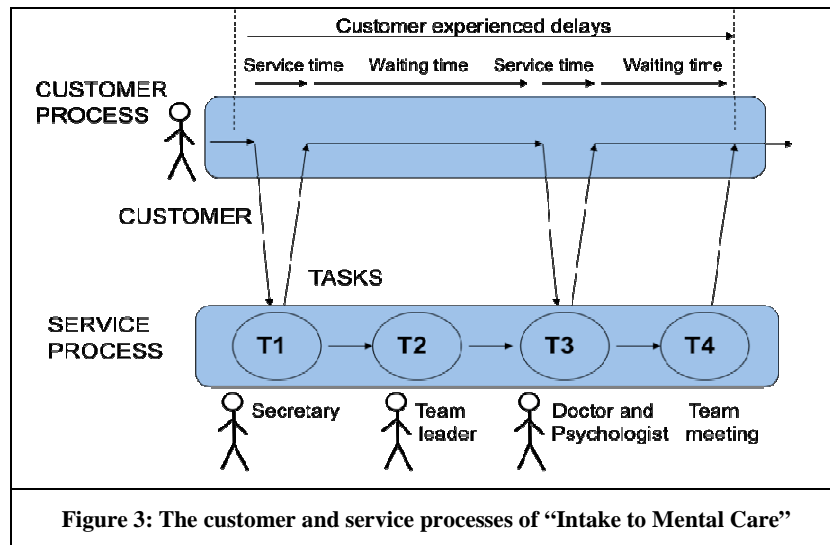
Next phase the customer obtains service is the interviews by the doctor and psychologist (task T3), after which the patient waits for results. The interview data is taken to the next Wednesday team meeting and the actions taken for the patient care are decided (task T4). This decision is communicated to the customer who enters to the next phase of service.

Figure 4: The utilization levels of the tasks before and after the changes

In the left panel of Fig. 4 we see that T3 is used only partly since it has a resource bottleneck. The example processes are improved by first taking into use an ICT application with which team leader can choose the intake doctor and psychologist without the weekly team meeting (T2). We add resources (one more psychologist) in the critical task T3 and as a result the cost per patient decreases and the throughput increases. Before the changes the activities T2 and T4 were the bottlenecks that prevent the event flow in the main activity T3. After the changes the bottlenecks have been solved and the full capacity of the activity T3 can be applied as seen in the right panel of Fig. 4.

When the costs of the customer and service processes are calculated, we see that before the changes the costs of the service and customer processes were high. The bottom of the U-curve representing the total cost per customer of the processes shows the optimal performance of old and new system of processes. After the changes one can see that in the optimal area the total costs of the processes decreased over 30%, the throughput doubled and the waiting times decreased 35%. The new system also becomes more flexible, meaning that the bottom of the U-curve of total costs is broader than before the changes (Figure 5).

Figure 5: The patient cost in the system before and after the changes
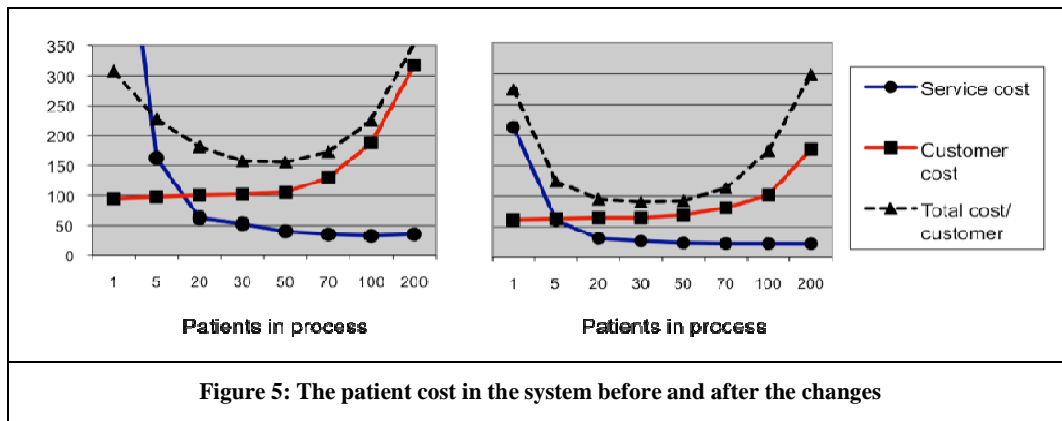
It is also easy to see from the models above that in the improved model the change from fixed cost resources to variable cost resources decreases the total cost less than in the case of the original process. With this example one can demonstrate three common paradoxes in process development:

1. Focused increasing of resources may decrease the total cost,

2. Outsourcing of resources and introducing variable cost instead of fixed cost improves cost-efficiency more if the processes are far from optimum,

3. Optimization of the service process costs without considering the customer process costs may drive the whole system far from optimal.

The last paradox is easily seen from the right side of Figure 5: When the process costs are in minimum, then the customer costs are in maximum and the total costs are far from optimum.

DISCUSSION AND CONCLUSIONS

In our example, the organization representing the health care sector was to carry out an ICT implementation to improve its business processes. We analyzed how ISs change business processes and how their improvements influenced the productivity. In so doing, we applied three different viewpoints, namely logical process diagrams, performance and cost. Our approach enabled the evaluator and IS management to examine and simulate the change even when it was not fully completed.

From the prior literature we know that a typical business process involves several stakeholders depending on the line of industry (Davenport, 1993; Emiris et al., 2001). Furthermore, Harkness et al. (1996) proposed to incubate process improvement activities in key areas through interfunctional partnering and information sharing outside of the formal business hierarchy. In our study we utilized a hypothesized example that was based on the study by Reijers (2003) and available information concerning the distinct activities related to the process. The process of "Intake to Mental Care" (see Figure 4) described by Reijers was evaluated with the 3VPM analysis.

Process improvement is striven with several approaches and frameworks. Prior research has recognized process modeling as a key function when seeking process improvements (Davenport, 1993; Hammer and Champy, 1993; Davenport, 1998; Maliranta and Rouvinen, 2006; Renzi et al., 2009). Furthermore, Kettinger et al. (1997) point out that problem solving and diagnosis are essential for basic problem analysis regardless of the project characteristics. Also, Melão and Pidd (2000) ask for further research incorporating pluralistic and multidisciplinary approaches. Our research introduced a solution to correlate ICT projects and process improvements that has offered a successful tool to analyze and evaluate the output at the time even when the change is in process as the input parameters can be changed in the 3VPM model.

In a sense, the 3VPM framework enables the decision makers to perceive learning by seeing what the proposed changes would mean in the process. The 3VPM approach also notices the resource-based view introduced by Melville et al. (2004) as the approach necessitates that a thorough skill matrix is built and the competencies of the employees are analyzed.

In practice, the process improvements were evaluated to be successful in several areas. If the process "Intake to Mental Care" (see Figure 3) is supported with an ICT application that adds transparency and possibilities to make changes in the process, the utilization levels of available resources may change dramatically (e.g. adding resources for task T3 in Figure 4). First, the

logical business process had to be described. After that, the true costs were calculated based on the parameters defined in Formulas 1, 2 and 3.

Similarly, analyzing the costs of the patients in process we could see changes in service costs, patient costs and total costs/patient. However, as demonstrated in Figure 6, we also identified three common paradoxes in process development as the minimized process costs produced patient costs and the total costs were far from optimum.

In all, our approach corresponds to the proposed problems found in prior literature. While many process improvements in practice are structural and the activities, resources or their relations in the process change with the improvements, our approach enables ICT professionals to use a methodology that allow structural changes in process models. Furthermore, the approach emphasizes the interacting process and therefore it considers the effects in the related processes. Finally, our approach strongly highlights the joint use of resources and personnel in several processes in an organization and the externality effects that the improvement in one process has to other processes via these joint resources in the organization.

In addition to introduce a new approach to analyze ICT enabled change process, we also recommend further research to explore the common paradoxes in process development. We challenge other researchers to investigate and evaluate ICT enabled process improvements and to find out which kinds of improvements would affect all or most stakeholders. Our approach offers a conceivable and feasible way to evaluate potential outputs even when the process improvement still is ongoing and changes are controllable.

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