E-Services and Productivity

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Key Words: *E-services; productivity; ICT; business process; process modeling; process improvement.*

Abstract. *Services are presently recognized as a source of productivity growth and dynamism in the economy. However, in the public sector, these productivity improvements enabled by services are not easy to recognize. On the contrary, negative productivity effects related to Information and Communication Technologies (ICT) investments have been reported. In this paper, we first consider how ICT changes services and how the productivity effects of these changes can be evaluated. Then, we analyze two cases, the Finnish Tax Administration and the Helsinki Central University Hospital Stroke Unit, and draw conclusions about the ICT investments and productivity. Finally, we report some findings on how ICT can be used to improve manual work processes. While business process modeling has been applied in organizations for decades, this paper presents a new approach to analyzing process benefits based on the introduction of ICT services on the hospital floor. We analyze and evaluate the benefits already in the planning phase of an ICT project, taking into account the dynamic nature of processes as they are realized in true work flows.*

Introduction

Turning investments in Information and Communications Technology (ICT) into higher productivity is not trivial but typically requires complementary investments and changes (Pilat 2004). Case studies and econometric work point to organizational complements such as new business processes, new skills and new organizational and industry structures as a major driver of the contribution of information technology (Brynjolfsson and Hitt, 2000). This complementary capital may be an order of magnitude larger than the investments in the computer technology itself (Brynjolfsson and Hitt, 2000, Brynjolfsson et al. 2002). Although successful computer investments generate returns within the first few years, greater output contributions accrue over 3-7 years. Consequently, only then can the realized productivity growth be seen (Brynjolfsson and Hitt, 2003). In contrast, the failure rate of information system projects is generally known to be high (Schmidt et al. 2001; Gunasekaran et al. 2006), and Furton (2003) confirms that evaluating success or failure is justified because failure is in fact more common in information technology projects than success.

There are many studies on the success and failure of ICT systems. Common to all of these studies is the idea that the benefits of ICT are related to complementary organizational and process changes. Difficulties arise with increasing complexity of the models, as well as with the incorporation of other more intangible aspects of information (Eatock, Paul and Serrano, 2001). Skills, competencies and information are often difficult to observe and model. The business processes (BPs) and the information systems (ISs) are closely correlated, and static modeling techniques cannot always predict these interactions. Three different subareas and their research traditions are interrelated: information systems, communication systems and processes (*figure 1*).

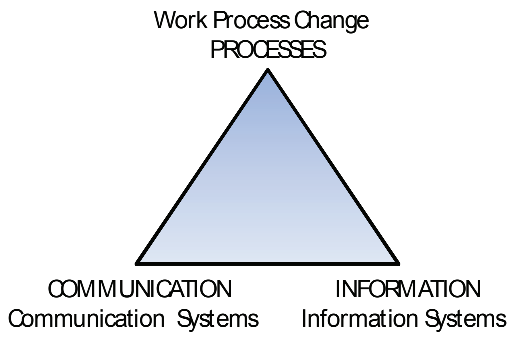

Figure 1. The three interrelated subareas

The performance of the process does not only depend on the information system behavior but on accurate changes to the business processes themselves (Paul and Serrano, 2003). There is a gap between ICT system features and optimal business process change. The existing business process and information system design approaches are not capable of modeling this interaction between BPs and ISs (Serrano and Hengst, 2005).

The concepts of performance and productivity differ in their meaning. The performance of a process refers to some features or parameters of the process that can be improved by process changes. Such features include throughput, service time, queue length, service quality or resource utilization. By productivity, we mean the ratio of certain outputs to certain inputs of a process. The output can be, e.g., the number of patients or events per unit time in the process, and the input can be person months in the process or monthly costs of the process.

In the Research Institute of the Finnish Economy (ETLA), the effects of Information and Communication Technologies and the corresponding performance and productivity of alternate process designs are compared using the 3VPM (Three Viewpoint Model) method (Martikainen, 2007). In the method, the processes are described qualitatively and quantitatively before and after the ICT implementation. By analyzing the process changes, the productivity benefits and possible drawbacks can be calculated. In the next phase, it is possible to assess what would be the most beneficial process changes to the customers, the employees and the organization and then to analyze which ICT solutions are capable of enabling these changes (Martikainen and Halonen, 2011). The method has produced results that have not been possible to obtain through other approaches, e.g., in the analysis of work processes and ICT implementations.

Special features of the 3VPM method include the description of different professional groups and, on the next level of complexity, the description of activity-related [dynamically generated] teams involving several professions. As an example, the Helsinki University Central Hospital (HUCH) involves 13 different professions combined into 21 different teams based on alternating combinations of these professions. The teams are modeled as groups of complementary and noncomplementary resources so that the optimal utilization of teams and resources is included in the solution (Naumov and Martikainen, 2011). This process of modeling teams with resources is new and has, to our knowledge, not been used elsewhere. Finally, the method takes into consideration „invisible work", which typically remains unidentified and unassessed in normal business process descriptions.

In the literature, there is a gap between ICT system features and optimal business process change; this is the gap that we try to fill. The gap results from several difficulties in modeling. First, many business process improvements are in reality structural improvements. However, the activities, resources or their relations in the process tend to change alongside with the improvements. We show in this paper how structural changes can be modeled using 3VPM. Second, the use of teams in activities creates nonlinear effects in the system: a missing team member may decrease the team productivity to zero. In the modeling of the HUCH Stroke Unit with 3VPM, it turned out that these team features were essential. Third, an operating real business process does not always behave according to the existing formal process specification used in the organization. These undocumented or hidden features of the real process are often essential to the potential process improvement development. Through the qualitative interviews that are part of the 3VPM method, we are able to document such hidden features.

Background

Traditional services differ from physical products in four ways (de Brentani, 1991). Services are intangible and cannot be fully assessed before their usage. Their production and consumption cannot be separated, and usually, an interaction between the client and provider is required. They are variable and may differ in every usage occasion. Moreover, services are perishable in the sense that the fluctuation of demand cannot be buffered by advance production and storing, which means that companies can incur high costs with underused resources when the service demand falls.

ICT-based services differ from traditional services because information technology partially frees services from place, time and the personal interaction required. The development and deployment of ICT-enabled services can be considered a form of production. The ICT systems related to services have to be developed, built and implemented, and the online services have to be constructed (Zysman et al., 2010).

ICT also enables the „industrialization of services", which means that services become scalable and tradable. Scalability means that economic growth is possible in trading services. Tradability means that services can be provided globally, which enables global specialization. Furthermore, services may enable endogenous growth, which is based on producing information from information and which can save other resources, such as energy, raw material and labor (Romer, 1986). Information-based services can also have increasing marginal utility, which is different from physical production. This industrialization of services can be seen in the statistics. For example, in Finland, 90% of work now involves something other than the production of goods (Pajarinen et al., 2011). Moreover, the productivity effects of ICT are greater in service firms than in manufacturing firms (Maliranta and Rouvinen, 2003, 2004). Extreme productivity change figures were detected when old manufacturing firms were compared with new service firms (*figure 2*). It must also be noticed that, on the industry level, half of the productivity improvements result from creative destruction. New firms enter and less productive firms leave the industry (Bockerman and Maliranta, 2007).

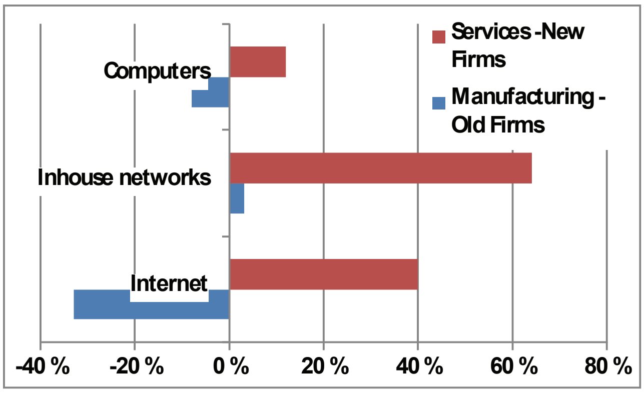

Figure 2. Labor productivity increase in firms based on ICT investments
(Adapted from Maliranta and Rouvinen, 2003)

Based on the same data, it was detected that some firms obtained very large productivity improvements from ICT investments. The question „How and what did these firms do?" was obvious from the data, and this started the microlevel service productivity research in ETLA in 2002.

The use of ICT for improving performance in public organizations was an important part of this research (Martikainen et al., 2006). In microlevel case studies, the observed productivity improvements of services enabled by ICT include three major groups (with average productivity improvement percentages) (Zysman et al., 2010):

- **Automated services** (70%) - These services rely on ICT or other technologies to deliver services that have been codified, digitized, and made available; e.g., banking and e-commerce.
- **Hybrid services** (50%) - These rely on a combination of humans and electronic tools to deliver services; e.g., education, insurance and travel.
- **Irreducible or augmented services** (17%) - These services rely on humans to deliver services, but the humans are augmented with ICT in some features of the services; e.g., health and social care.

In real cases, the productivity improvement percentages can vary greatly from the given average figures above. Moreover, when services have been improved with ICT, only a temporary competitive advantage can be obtained. This means that constant innovation is necessary.

Though there is a gap in the literature between the ICT system features and the optimal business process change, there are, however, a large number of studies on special organizational IT systems related to processes: the Enterprise Resource Planning (ERP) systems. The fact that ERP systems can lead to significant cost savings and increased profitability has contributed to their widespread adoption since the mid-1990s (Trunick, 1999, Booth et al., 2000, Madapusi and D'Souza, 2005, Dery et al., 2006). Reduced procurement costs, smaller inventories, more effective sales strategies, lower administration costs and reduced direct and indirect labor costs have been reported (Davenport, 1998; Buckhout et al., 1999; Laughlin, 1999; Hunton et al., 2003; Gefen and Ragowsky, 2004; Yen and Sheu, 2004; Bergstr□m and Stehn, 2005). However, there have also been observations that between 60 to 90 percent of ERP implementations fail to achieve the projected return on investment (Trunick 1999), that 40 percent of ERP implementations are only partially completed and that 20 to 50 percent are scrapped as failures (Laughlin 1999).

Research Methodology

When a service is provided for a customer's business process or personal process, the interaction with the service process changes the customer process in a way that creates productivity improvements. Usually the utility of the productivity improvements should be larger than the cost of the service. However, in public services, the utility is not only the performance improvement in the customer's process but also the utilities created through externalities in the society (*figure 3*).

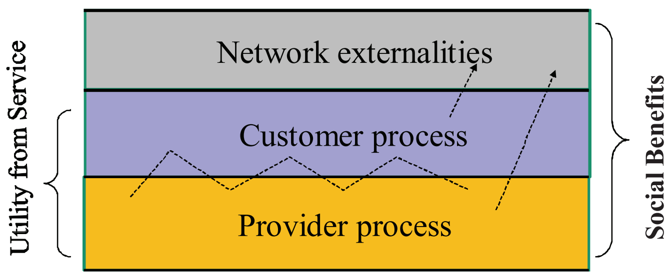

Figure 3. The benefits created by a service process

In addition to the process diagrams, both performance and cost modeling of the processes are needed when productivity improvements are analyzed. We call the modeling approach that uses these three viewpoints - 1) diagrams, 2) performance and 3) cost - the 3VPM approach. For performance, we use queuing network models to calculate the throughput and waiting times of events or tasks in the process as well as the utilizations of resources related to the activities of the process. In cost analysis

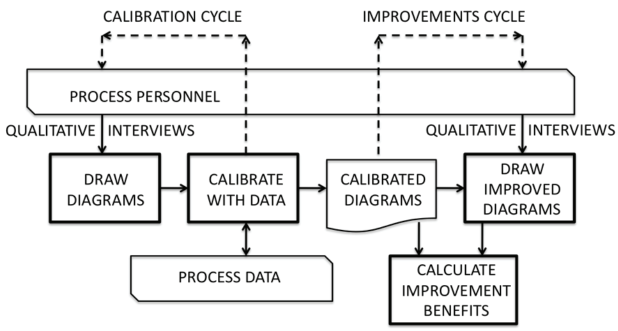

Figure 4. The four analysis steps of the 3VPM used to evaluate service benefits (Source: Martikainen and Halonen, 2011)

calculations, the fixed costs in the processes are related to the costs per unit time of the fixed resources involved as well as to the fixed quality costs and the fixed risk costs. The variable costs of the process are related to the product of the utilization and the cost per unit time 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.

Three Viewpoint Model

The Three Viewpoint Model (3VPM) approach has four analysis steps for evaluating the process changes enabled by an ICT service (*figure 4*) (Martikainen and Halonen, 2011): 1) Draw diagrams, 2) Calibrate with data, 3) Draw improved diagrams and 4) Calculate improvement benefits.

Draw Diagrams

The first step is to draw logical process diagrams to describe the workflow in phases. This is done together with the employees using semistructured interviews with the aim of producing 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 (see Eriksson and Penker 2001).

Calibrate the Model

The second step was to analyze the process performance (see Formula 2) and costs (Formula 3). The variables used in the 3VPM are activities or tasks (A_i), related resources (R_k), groups of resources called teams and serving in activities, customers (E) served, customer arrival intensities (λ_i) to the system, routing probabilities (ρ_{ij}) of customers between activi-

INPUT VARIABLES		OUTPUT VARIABLES	
Activities or tasks	A_i	Customer time in activity	W_i
Customer classes	E_p	Customers p in system	N_p
Routing probabilities of class p customers	π_{pij}	Customers in activity i	N_i
Service time of customers of class p in activity A_i	T_{pi}	Customers of type p in activity i	N_{pi}
Arrival intensity of customers of class p in A_i	λ_{pi}	Utilization of activity	ρ_i
Amount of resources of type k	R_k	Utilization of resources of type k in activity i	ρ_{ki}
Service rate of team m in activity i	S_{mi}	Utilization of team m in activity i	ρ_{mi}
Amount of resources k needed in team m	R_{km}	Number of teams m allocated in activity i	X_{mi}
Resource k cost in time	C_{Rk}	Fixed costs	C_F
Activity i other costs	C_{Ai}	Variable costs	C_V

ties, 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 an extended queuing network solution for model M denoted by G and the cost analysis solution using a function denoted by F. We extend the queuing network solution (Denning and Buzen 1978; Gelenbe and Pujolle 2001) by finding out the optimal fractional allocations of the teams of resources in the network (Naumov and Martikainen, 2011). This extended solution G provides the maximum throughput of the system (Denning, 2008). The input and output variables are displayed in *table*. Formulas 1, 2 and 3 define their interrelations.

(1) $M = (A_i, E_p, \pi_{ij}, T_{pi}, S_{mi}, R_{km}, S_{mi}, C_{Rk}, C_{Aj});$

(2) $(\lambda_{pi}, \rho_i, \rho_{ki}, W_i, N_p, N_{pi}, X_{mi}) = G(\lambda_{pi}, R_{km}, M)$ and $R_k \geq \Sigma_{mi} R_{km} X_{mi};$

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

The model M includes the process components and the variables of the calibrated diagrams. The function G is the extended solution of the queuing network representing the process or processes involved. 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*, the variables are given in the case in which the model M is an open queuing network.

Solving function G for the model M and the variables λ_{pi} and R_{km} in Formula (2) constitutes the performance analysis. The resources, such as employees and equipment, are classified as resource types R_k and assigned in teams R_{km} to the activities they are capable of performing. Based on the teams, the optimal resource distribution over the activities with the boundary condition $R_k > \Sigma_{mi} R_{km} X_{mi}$ of Formula (2) can be calculated, and we denote this optimal solution as G. The calculation reveals, for example, the optimal allocation of resources to teams that can be assigned to the activities. The resource distribution of the original and improved process models can now be compared, and the improvements in resource utilization levels can be analyzed. The joint use of resources that is specified in the teams and the included optimization algorithm 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.

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 implies comparison of existing real process performance statistics to the corresponding results given by the analysis tools. If the calibration does not match, iterative interviews are needed to correct the process diagrams and their variables. This creates more insight into the process behavior. In some cases, experimenting with the process variables, such as „incorrect delays“ or possible „hidden work times,“ has been needed to reveal and correct the factors that prevent successful calibration. This is the calibration cycle (*figure 4*). Only after successful calibration can the possible process changes be modeled and their effects analyzed.

Draw Improved Diagrams

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 in which the possible improvements enabled by the ICT system are analyzed. This procedure is called the improvement cycle (*figure 4*). Let us denote two possible improved models of M as M_1 and M_2.

Calculate Model Change Benefits

Before the comparison of the original and improved models can be made, the function G has to be solved for each of the models. If resources in teams are used, then the optimal function G can also be obtained for the models. Let us denote the resulting variables of the solution $G(\lambda_{pi0}, R_{ki}, M)$ of Formula (2) using the following notation: $\lambda_{pi} = G(\lambda_{pi0}, R_{ki}, M)(\lambda_{pi})$.

The service level obtained by a customer class p in model M can be expressed as the throughput λ_{pi} for some activity i. The service level or throughput improvement of model M_1 compared with model M can be calculated from Formula (a)

(a) $\Delta\lambda_{pi} = G(\lambda_{pi0}, R_{ki}, M_1)(\lambda_{pi}) - G(\lambda_{pi0}, R_{ki}, M)(\lambda_{pi}).$

We obtain the resource improvements $\Delta R_k = R_k - R_k$ related to a constant service level λ_{pi} from Formula (b)

(b) $G(\lambda_i, R_k, M)(\lambda_{pi}) = G(\lambda_i, R_k, M_1)(\lambda_{pi}).$

The utilization improvement of resources in activity i related to a constant service level λ_{pi} can be calculated from Formula (c)

(c) $\Delta\rho_i = G(\lambda_{pi0}, R_{ki}, M_1)(\rho_i) - G(\lambda_{pi0}, R_{ki}, M)(\rho_i).$

Similar formulas can be written for other variable improvements by keeping some reference variable constant; the improvements can be expressed as absolute or relative quantities.

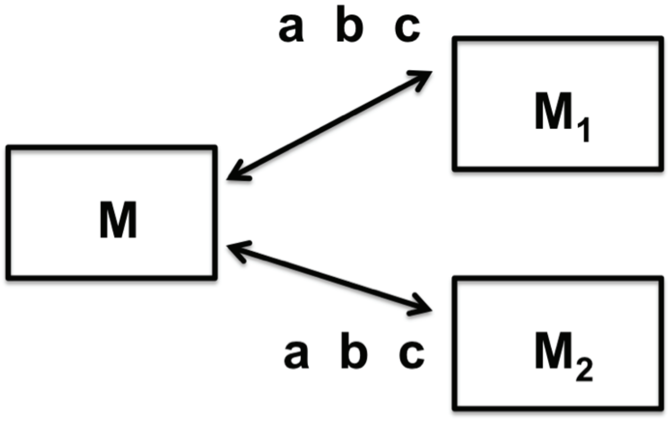

Figure 5. Original model M and improved models M_1 and M_2 are compared with Formulas (a), (b) and (c)

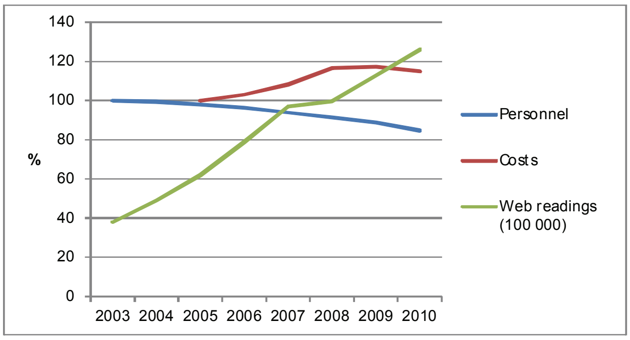

Figure 6. Finnish Tax Administration Statistics (Source: Finnish Tax Administration 2007, 2010)

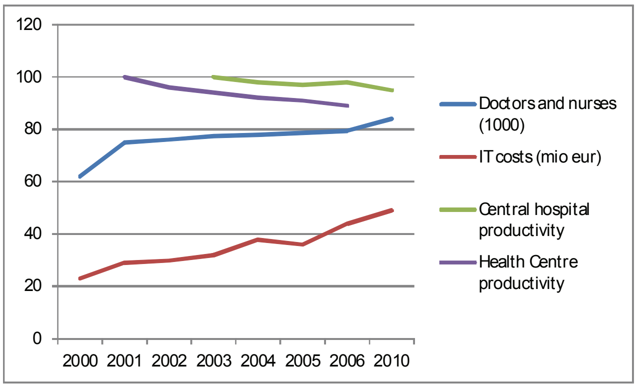

Figure 7. Finnish Health Care Statistics (Source: Luoma, 2010)

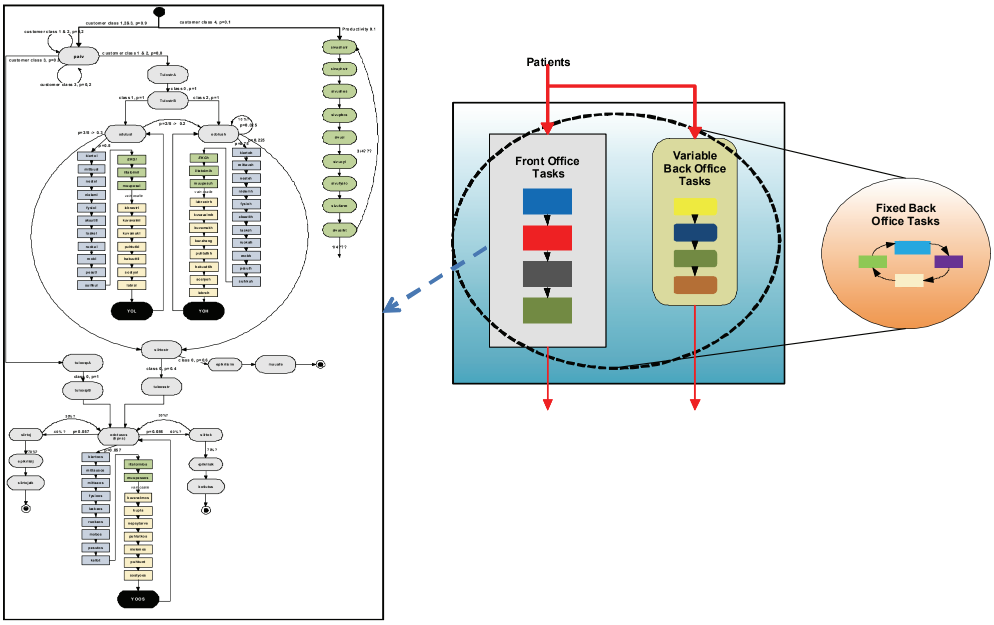

Figure 8. HUCH Department 92 processes (Front Office enlarged on the left)

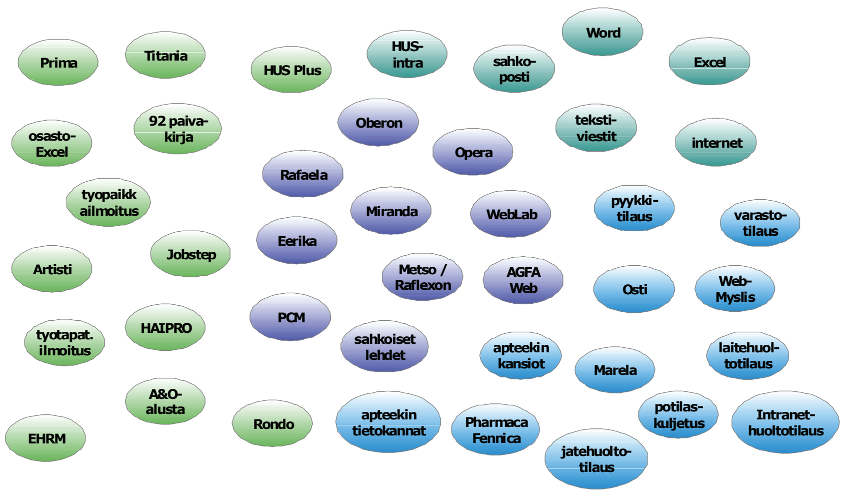

Figure 9. The applications used in HUCH Department 92

Examples

Finnish Tax Administration

The productivity program of the Finnish Tax Administration started in 2003 with e-Services development (The Finnish Tax Administration 2007, 2010). In this program, the number of employees decreased by more than 15%, but the cost per employee increased (*figure 6*).

However, there is a major improvement that does not appear in the statistics. The annual tax announcement form filling time of individual taxpayers is estimated to have decreased by more than four hours per year on average. This conservative estimation would suggest a saving of 5000 person years annually, which is approximately the amount of employees in the entire Tax Administration.

HUCH Stroke Unit

In the Finnish health care sector, IT services have been heavily used since the 1990s. Web-based services are used for appointment reservations, medical advice and general information, and patient information is stored and available for professionals. The ICT systems in health care have been focused on data collection and data integration. During 2000-2010, health care costs increased and productivity decreased (*figure 7*).

The Stroke Unit (Department 92) processes of Helsinki University Central Hospital (HUCH) were analyzed in ETLA using the 3VPM approach (*figure 4*). In Department 92, the processes were more complicated than any of the 50 processes studied in ETLA during 2006-2011, including several industry sectors. In the Stroke ward, there were 13 professional groups working in 21 alternating teams. The process descriptions include three groups of tasks: Front Office, Variable Back Office and Fixed Back Office tasks (*figure 8*).

There were 40 ICT applications in use in the department (*figure 9*). These applications included features for data collection, but they also decreased the productivity of the personnel. Two major implications were obtained:

Implication 1. Create work process improvements with applications that can tap into the extensive vested knowledge of the work force in each professional group.

Implication 2. Use highly differentiated, configurable and task-conscious mobile solutions to automate and augment work.

Conclusion

Services are presently recognized as a source of productivity growth and dynamism in the economy. However, in the public sector, these productivity improvements enabled by services are not easily recognized. On the contrary, negative productivity effects related to ICT investments have been reported. In this paper, we have examined how ICT changes services and how the productivity effects of these changes can be evaluated.

Our approach fills some of the gaps found in prior literature. Many process improvements are structural in practice, and as the activities, resources or their relations in the process change together with the improvements, our approach enables ICT professionals to use a methodology that allows structural changes in process models. An operating real business process does not always behave according to the existing formal process specification used in the organization. These undocumented or hidden features of the real process are often essential to the potential process improvement development. Furthermore, our approach emphasizes the process intenactions, and therefore, it considers the effects in the related processes. Finally, our approach strongly highlights the complementary and noncomplementary use of resources and personnel in several processes in an organization as well as the externality effect that the improvement in one process has on other processes due to simultaneous resource usage in the organization.

We challenge other researchers to investigate and evaluate ICT-enabled process improvements and to identify which kinds of improvements would affect all or most stakeholders. If the productivity of public services could be improved by 10, 20 or 40 percent, most of the financial problems of the present welfare state would be solved. We have shown in our R&D cases that productivity improvements of this kind in services are possible with ICT.

Acknowledgments

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