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The conference featured invited keynote talks of leading experts from industry and academia and selected workshops from different fields of computer science, mostly covering the general conference topic "Service Science – New Perspectives for Computer Science" ("Service Science – Neue Perspektiven für die Informatik").

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Lecture Notes in Informatics

Witold Abramowicz, Rainer Alt, Klaus-Peter Fähnrich, Bogdan Franczyk, Leszek A. Maciaszek (Eds.)

INFORMATIK 2010

Business Process and Service Science – Proceedings of ISSS and BPSC

September 27 – October 1, 2010
Leipzig

Proceedings

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Preface ISSS 2010

Some five years ago, the first seminal contributions on Service Science have spurred numerous research activities in academia and practice. Today, the lead conference of the German Computer Association has adopted the theme 'Service Science' and many researchers have engaged in shaping this promising research field. A large potential is attributed to linking the research on design and management of economic and technological services, thus two domains which have mainly evolved separately. However, the unique characteristics, principles, instruments and benefits of Service Science are still subject to further research. For example, this includes the advantages compared to existing approaches, such as engineering of hybrid products, (business) process management, or distributed information architectures.

To establish a platform for interaction between researchers in this emerging discipline the 'International Symposium on Services Science (ISSS)' was organized at the University of Leipzig for the first time in 2009. Following the integrating nature of Service Science it brought together representatives from economics, information management as well as from computer science. The same goals also apply to ISSS in 2010 which attracted a total of 25 scientific contributions. Nine papers were accepted which makes an acceptance rate of 36%. Remarkably, all papers originate from German speaking countries even through the ISSS also received non-german contributions and the program committee was international in nature.

The accepted papers were compiled in three clusters. First, service management comprises research on Service Science as enabler for innovation in collaborative business settings. These papers deal with managerial challenges, methods and technologies. Two interesting case studies from the banking and fashion industry provide an impression on the implications of service science in today's business and the perspectives. Second, the area of service engineering comprises methods, standards and modeling techniques for strengthening the engineering perspective. In addition to case studies, the papers report on innovative prototypes and service interactions. Finally, service delivery deals with some of the application areas and how the integrated view of Service Science might enhance business processes.

Altogether, ISSS 2010 would not have been possible without the support of the academic community and the members of the local organizing committee. We highly appreciate the support of the 43 program committee members who made it possible, that all papers underwent a strict double-blind review process. Among the local organizers many thanks go to Stefan Döbelt and Olaf Reinhold from the University of Leipzig. They not only managed the information on the conference website and the communication with authors and reviewers, but also the intricacies of the review system. Finally, we hope that the papers included in this volume stimulate research on Services Science and foster further work in this promising area.

Leipzig, August 2010 Rainer Alt

Preface BPSC 2010

The papers published in this volume were presented at the 3rd International Conference on Business Process and Services Computing (BPSC 2010) held in Leipzig Germany on 27-28 September 2010. The BPSC conferences present and publish research findings and IT industry experiences with relation to process-centric service-oriented development and integration of enterprise and e-business information systems. By looking at the convergence of business processes and services computing, BPSC conferences identify most hopeful trends and propose new directions for consideration by researchers and practitioners involved in large-scale software development and integration. The background principle is to consider process management as a new paradigm with semantics and meta-models radically different from applications that merely implement business processes.

The book includes papers selected for presentation at BPSC 2010 in the rigorous review process. To ensure quality and consensus among the majority of the reviewers, most papers received three or four reviews and some papers were subjected to as many as five or six reviews. The acceptance/rejection decisions were solely based on the averages of scores given by the Program Committee members consisting of researchers of a very high standing in the subject area of the conference.

The Program Committee was chaired by Salima Benbernou (Paris Descartes University, France) and Mike Papazoglou (Tilburg University, The Netherlands). The bulk of the organizational work, including the maintenance of the conference website and the setup and management of EasyChair as the conference management tool, was performed by Andrzej Niesler (Wrocław University of Economics, Poland). Alexandra Gerstner (University of Leipzig, Germany) provided necessary organizational support for BPSC 2010 as part of INFORMATIK 2010, including putting this volume together for publication.

As the conference originators and as the Steering Committee of BPSC 2010, we were privileged to work with all these people and would like to thank them for the work done so well. Moreover, very personally but also on behalf of the authors of all submitted papers, we would like to express our warmest gratitude to the PC members for very helpful in-depth reviews.

Witold Abramowicz (Poznań University of Economics, Poland) and
Leszek Maciaszek (Macquarie University ~ Sydney, Australia and Wrocław University of Economics, Poland)
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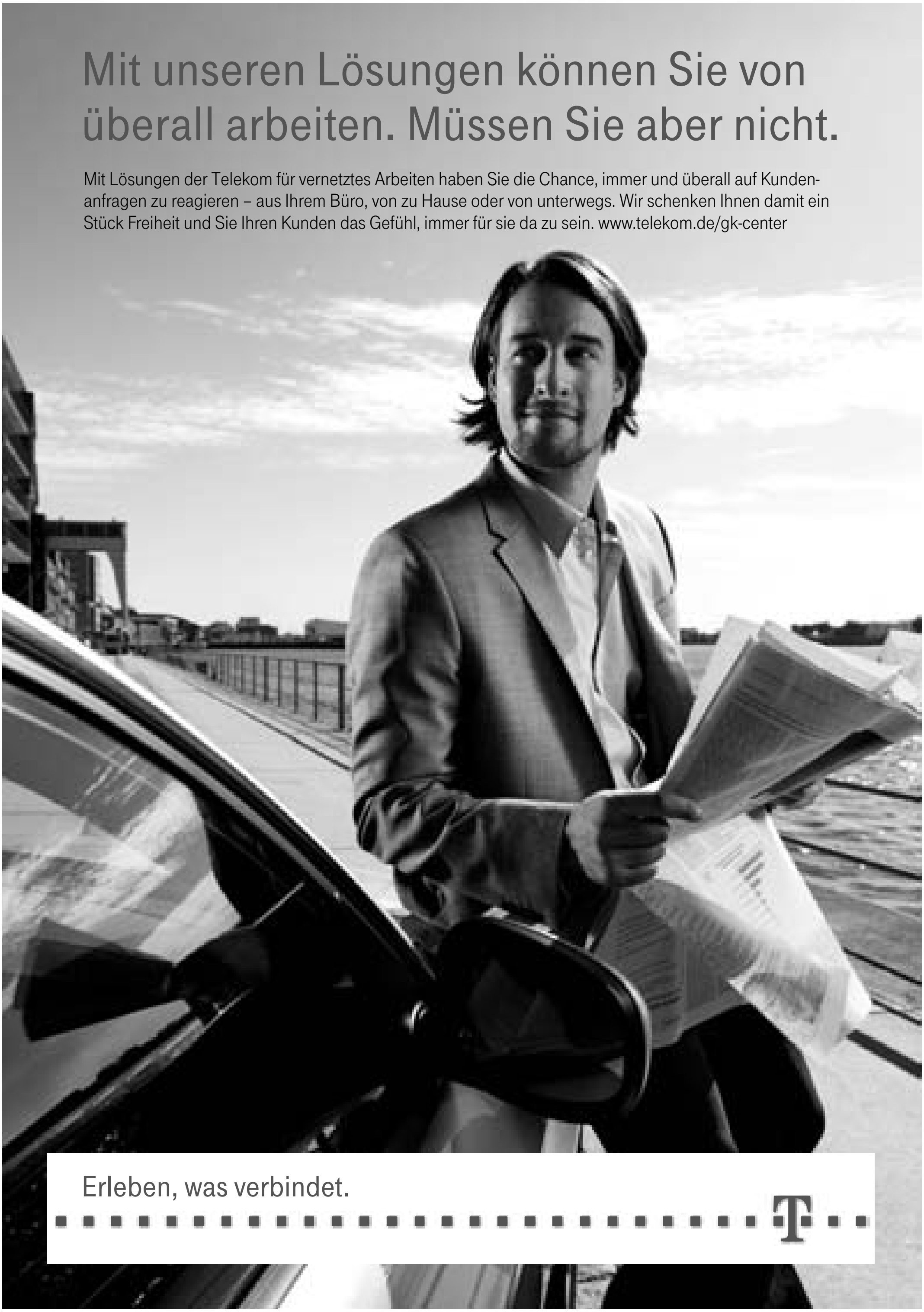
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Conference

Second International Symposium on Services Science (ISSS 2010)

Rainer Alt

Activating the Innovation Potential of SME: The Bottom-Up Approach

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Abstract: In this paper we propose an innovation model for the collaboration between SME and public research institutions in order to enhance knowledge transfer and to foster the creation of a regional innovation network. A third aspect is to enhance a more intense cooperation in the public research sector between institutions and departments. In this paper we discuss the term innovation and describe the following aspects: (1) the general idea of the developed bottom-up innovation model, (2) the organizing framework of the participants in the network and (3) the procedure in the innovation process.

1 Innovation is the Key

Successful innovation is the basis of a competitive economy and sustained economic long-term growth. Research and development (R&D) accounts for nearly half of the economic growth in the U.S. [PK03] [AW08]. As innovation cycles become shorter and development costs continuously increase, companies are under constant pressure to adjust their innovation development and management schemes. Nowadays it is more and more essential to collaborate with other businesses, customers, institutions and even with competitors in order to include expertise not covered by the company itself into the innovation process. Using open innovation in order to share internal and integrate external knowledge within the process of idea generation, research, development and commercialization stages help to reduce costs and risks of innovation schemes [Ch03]. The open innovation paradigm provides the opportunity to pursue innovations which do not fit into the current company strategy or to commercialize ideas generated outside the company [PD09] [GE06]. Furthermore, innovations are increasingly not developed by one single company, but are more and more created cooperatively through an entire value chain with several companies involved. Especially high-tech businesses such as information and communication technologies are forced to open up their internal innovation process and band together in networks to adjust to the global evolution pace. For small and medium-sized enterprises (SME) it is vitally important to create innovation networks, as they are frequently neither able to provide all skills needed in the R&D process due to limited human resources nor do they possess the financial capability to run a research laboratory.

The proposed innovation model for the collaboration between public research institutions and SME deals with the questions (1) how to enhance the knowledge transfer between SME and research institutions, (2) how to overcome restricted resources in SME and thereby (3) activate innovation potential of SME. The model has been developed based on the idea of bottom-up innovations (see 6.). It has been elaborated and adjusted iteratively by applying the framework in practice. The approach is being supported by the development of additional methods and tools which are described in [MT10].This approach has been documented in over 50 exploratory case studies [Yi03] [MT10]. In this paper, first we discuss the term innovation; then we describe the general idea of the developed bottom-up innovation model, the organizing framework of the participants within the network and the proceeding in the innovation model. The main goal of our approach is to create a regional innovation network with public research institutions as the driving force in order to boost the regional innovation potential.

As service science is interdisciplinary and is examined from different scientific points of view and backgrounds such as computer science, marketing, psychology and many other disciplines, intense relationships in the research sector are likely to generate benefits and stimulate new approaches. Recent research in Germany has produced internationally acknowledged findings, for example in the field of service engineering. This approach was originally designed with the idea in mind to transfer the methodical knowledge existing in order to enhance a systematical service development in SME, but the approach is not limited to this scientific background and can be adopted in, or combined with, other areas.

2 Technology Push and Demand Pull

The trigger for innovation can be divided into two streams: technology push and demand pull [Ha04]. Technology push means that research gives rise to new technologies or applications that are thereafter applied to create new solutions. Demand pull means that the market signals a need for a solution to a particular problem which is then solved in the innovation process. The 1970s debate about the impact and importance of each of the triggers came to the conclusion that a separated view would be leading nowhere. In practice, innovation is a coupling and matching process where interaction is essential. Successful innovation requires the interaction between (technology) “push” and (demand) “pull” actors. Typical push actors are public research institutions, while SME are typical pull actors.

In reality, public research institutions often have no or poor contacts to local SME and vice versa. The interaction between these actors is strongly limited. In fact, linear push-pull models still influence much practice and debate, especially in financing public research, although more realistic dynamic models have been proposed [MP07] (see [Ti06] for a review on literature). Research of the (public) push actors is usually guided by personal interest or public funding programs. One can observe a priority in public funding programs to promote cutting-edge research in specific industries identified as key technologies, currently bio-, nano- and microsystems technologies that focus on path-breaking product and process innovations. With that being the case, the organization of the knowledge transfer resulting from research activities is commonly organized top-down and can be described in terms of the traditional waterfall-model known from software engineering [Ro70]. In this model, impact research triggers the development of basis innovations which result in new innovative products or processes [Ed97] [RS06]. These products or processes are gradually commercialized and create new or invigorate existing markets. It can be seen as the classic way from basic research, through applied research, engineering, development and product design, to commercialization [RZ85]. This approach aims to produce market or niche market leaders in high-tech and skill-intensive sectors with major value creation, high growth rates and new employment. This approach is widely established and has been validated through many successful developments and major breakthroughs in the past years. The disadvantage of this approach is that the research is done prior to identifying useful applications of the findings. The top-down organization of research activities and knowledge transfer is especially disadvantageous for SME, as useful related output is often generated by coincidence or in the worst case misses the needs completely. The German approach of funding so-called "Verbundprojekte"[1] has attracted worldwide attention and is clearly a step forward to overcome the simple linear top-down model.

The aspect of demand pull, and especially concerning the needs of SME, has been disregarded in the development of public R&D subsidies. Recently, one can see a shift and a higher notice of these actors, as special funding is provided to strengthen the innovation potential and interaction with research institutions (e.g. the so-called innovation vouchers or innovation assistant programs).[2]

3 What is Innovation?

Innovation is a stylish term used in many contexts; yet it lacks a single definition. A variety of literature has accumulated around the topic of innovation management examining the topic from different scientific backgrounds [ABP06]. Over time many definitions, distinctions and classifications have evolved [Ha04]. Therefore, it is necessary to clarify the meaning of the term innovation used in this context. On the scientific level, this classification is important in order to be able to classify and compare the findings. Many scientific studies are not comparable because of an inconsistent understanding of innovation [TK82]. On the practical level, defining the term´s meaning is important in order to use the right methods and tools in the innovation process.

Schumpeter was the first to coin the term innovation [Sc39] for the use in business studies [TS07]. Logically, the definitions of the term proposed by different authors are

[1] Verbundprojekt translates into joint research project

[2] For more information see www.innovationsgutscheine.de; www.innovationsgutschein-bayern.de or http://www.innovation.nrw.de/wissenstransfer/kleine_und_mittlere_unternehmen/innovationsassistenten/index.php

close to his ideas of creative destruction and the classification into the innovative entrepreneur and the entrepreneur's imitators [Sc31]. First of all, it is necessary to distinguish the terms idea, invention, innovation and imitation, especially with regard to the knowledge transfer aspect of this approach. An invention stands for an idea made manifest, while innovation describes ideas applied (successfully) in practice. There is a general consensus in the scholarly literature that innovation consists of invention and its first exploitation [Ve80] [Sc66] [Ki69] [Ro83]. Second, it is necessary to distinguish innovation and imitation. Innovation describes the first successful application of an invention or solution while imitation describes a reproduction or replication of an already developed invention or solution. At first this distinction seems to be clear. In fact, it is a matter of individual determination of when the line between imitation and invention is crossed or of how significant the change has to be. For example, from the (subjective) point of view of an imitating company, changes are a completely new field of action and can be seen as innovation. Usually, inventions are not imitated by several companies in the same way, but are adapted to the individual needs and are, therefore, slightly different, particularly organizational or process innovations. Thus the bottom line is that innovation is an improvement of an existing solution (incremental innovation) or a creation of a completely new solution (radical innovation) without a clear specification of the dimension of the change.

For the purpose of transforming existing knowledge and dealing with the innovation potential of SME, we require a "soft" definition of innovation. The OECD definition distinguishes and defines four types of innovation: product, process, marketing and organizational [Oe10] (see table 1).

Product Innovation	This type involves new or significantly improved goods or services including significant improvements in technical specifications, components and materials, incorporated software, user friendliness or other functional characteristics. In the education sector, a product innovation can be a new or significantly improved curriculum, a new educational software etc.
Process	Process innovation involves a new or significantly improved production or delivery method. This type includes significant changes in techniques, equipment and/or software. In education, this can be a new or significantly improved pedagogy.
Marketing Innovation	Marketing innovation comprises a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing. In education, this type can, for example, be a new way of pricing the education service or a new admission strategy.
Organisational Innovation	Organisational innovation involves introducing a new organizational method into the firm's business practices, workplace organization or external relations. In education, this type can, for example, be a new way of organizing work between teachers, or organizational changes in the administrative area.

Table 1: Four Distinctions of Innovation, source: [Oe10]

More importantly, the definition states:

> *"These innovations can be new to the firm/educational institution, new to the market/sector or new to the world".*

This meaning allows us to consider adaption of existing solutions on company level as innovations ("new to the firm"). Likewise, this definition describes the dimension of the change as "significant", giving room for interpretation. For our purpose, we assume that every change has a positive effect on value creation, cost reduction etc. as innovation, no matter how extensive the action or effect is. If, for example, a change of color of a product results in a higher price for which the product can be sold, then from our point of view we face an innovation process (in this case the action classifies as marketing innovation). Using Tidd's and Bessant's [TB09] words:

> *"...we should also remember that it is the perceived degree of novelty which matters; novelty is very much in the eye of the beholder. For example, in a giant, technologically advanced organization like Shell or IBM advanced networked information systems are commonplace, but for a small car dealership or food processor even the use of a simple PC to connect to the internet may still represent a major challenge."*

That is, we do not focus on low-end incremental innovations, but nor do we wish to exclude them, as SME are likely to require simple solutions or adaption of existing knowledge, in our case provided by the research and transfer institutions.

4 The Bottom-Up Innovation Model

Rothwell [Ro92] describes five generations of innovation models: the technology push model (1st generation), the need pull model (2nd), the coupling model (3rd), the parallel lines model (4th) and the integrated systems and networking model (5th). Marinova and Phillimore [MP07] extend Rothwells typology and describe six generations (see table 2).

G	Innovation Model	Description
1st	black box model	Innovation needs inputs and creates outputs. Process of the transformation is not analyzed.
2nd	linear models (technology push and need pull)	The innovation process is a linear sequence of functional activities.
3rd	interactive models (coupling and integrated models)	Interactions between several (internal) actors linking the in-house functions and linking to science (state of the art).
4th	system models (networking and national systems)	Cooperation between many (internal and external) actors linking in innovation networks using synergies.
5th	evolutionary models	Innovation as an evolutionary process of generation, selection and survival of the fittest with high dependence on the background.
6th	innovative milieu	Regional innovation cluster, collective learning and importance of geographical location.

Table 2: Six generations of innovation models, author´s illustration based on [MP07]

We propose an approach to create an innovative milieu on the basis of a system model in the field of knowledge transfer between public research institutions and SME. The aim is to create a regional innovation network with the research institutions as the driving force. In the system model, firms that do not have the resources to cover the whole innovation process can benefit by establishing a network in order to share knowledge and resources. Hobday [Ho91] summarizes the benefits of the collaboration as follows:

- groups of SME can maintain leading edge technologies by using support from each other and by sharing costs;
- collaboration enables skill accumulation and collective learning for the benefit of all participants of the network;
- collaboration increases the exchange of key individuals between the firms;
- skills can be combined and recombined to overcome bottlenecks;
- innovation time and costs can be reduced;
- the network provides entry into the industry for small innovative firms;
- individual firms within the network operate with high flexibility and in low-cost ways including small overheads.

Participating in networks enables access for SME to regional experience and knowledge pools but the real strength lies in links to global networks [St00]. By adding public research institutions to the network, SME gain access to state-of-the-art knowledge and technology. This innovation network is supposed to grow into an innovation milieu. Camagni [Ca91] describes the components of an innovative milieu as follows:

1. a productive system
2. active territorial relationships
3. different territorial socio-economic actors
4. a specific culture and representation process
5. dynamic collective learning

The interactions creating the innovative milieu are not necessarily based on market mechanisms, but include movement and exchange of goods, services, information, people and ideas among one another. They are not always formalized in cooperative agreements or any other contracts. Major features of such an environment are the ease of contact and trust between the partners, which reduces uncertainty in the development of new technologies and proves to be a source of exchange of tacit knowledge [CC00].

5 The Organizational Framework

The proposed model contains all of the above components. The actors in the model include SME, public research institutions and local associations and chambers being used as gateways to company contacts (3. different territorial socio-economic actors). The bottom-up innovation process is the core of the approach (1. 2. and 4.), focusing on idea development and inter-organizational cooperation (5.) (see figure 1). In our approach the public research institutions play a central role as the driving force behind the regional innovation system. They are supposed to manage the network, attract new members and initiate innovation projects and knowledge transfer activities. An obstacle that has to be resolved is the institutional barrier in the collaboration between research institutions and departments, the biggest challenge probably being in the motivation of single departments to take part in the process. Typically, departments work isolated from one another and do not try to identify possible cross-research activities and benefits nor do they share their industrial contacts. Preferably, as many departments as possible merge together in order to include expertise and knowledge from different scientific backgrounds. Other barriers are the typical collaboration problems such as asymmetric information, communication, spatial distance etc. Therefore, competence and expertise of every participating institution has to be identified and classified. Building on that, an internal communication strategy has to be installed. We developed several instruments in order to overcome the barriers. The creation of a competence matrix summarizes all previously defined fields of expertise of the participating institutions in the project consortium. A responsible person to contact is appointed. This process of a deep self-analysis helps to identify potential gains of a closer collaboration among each other. The launch of an online communication environment consisting of a server that allows online file sharing, group discussions as well as contact, calendar and information management, helps to overcome the spatial and information barriers. This online collaboration environment is also used in the collaboration with companies during the work in single innovation projects. An intern glossary of important key words helps to reduce misunderstandings.

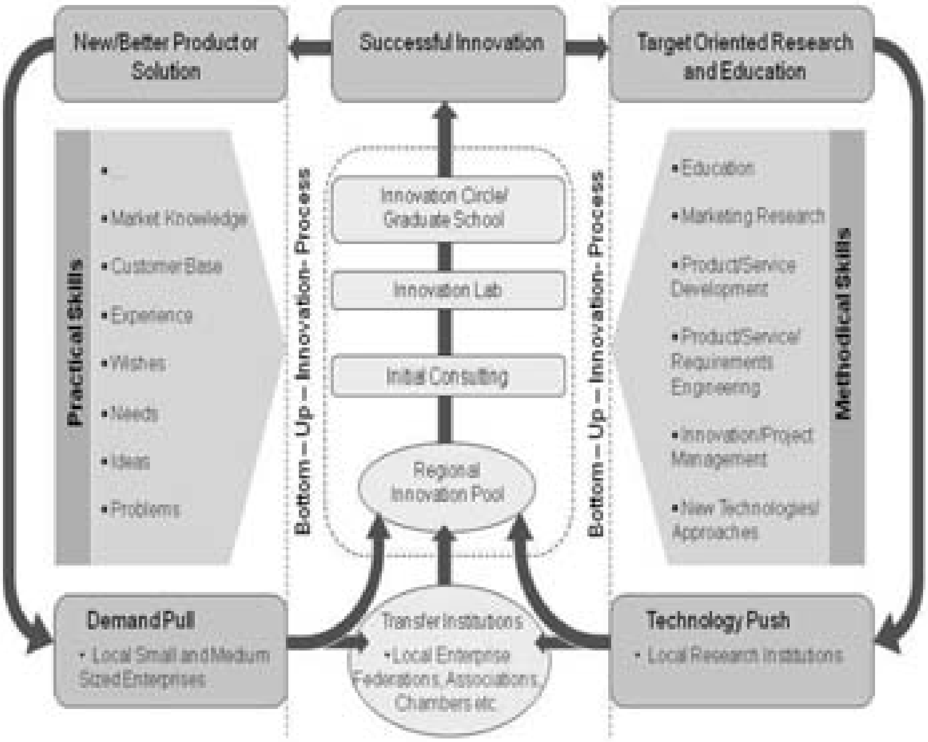

Figure 1: The Bottom-Up Innovation Model, author´s illustration.

Using local industries associations, chambers, federations etc. enables easier contact to local SME and includes more know-how and knowledge, especially in the knowledge transfer sector, into the network. In the model we assume an existing regional innovation pool that arises from the knowledge, experience, ideas and know-how of the described actors in the regional innovation network. With the bottom-up innovation process we describe a way to bundle the existing practical and methodical skills of the partners in order to exploit successfully the innovation pool.

6 The Bottom-Up Innovation Process

The purpose of the bottom-up innovation is to cooperate closely with businesses, strengthen the relationships to local SME and consider their needs and problem statements in the structuring of research activities. The idea is to open up space in which business and education could meet at a basic level discussing everyday problems and identifying needs, innovation potential and possible research activities. The core of the idea is to examine the innovation chain backwards; i.e. “bottom-up” instead of “top-down” based on value creation chains and customer needs. The difference in such a setting is that the approach is problem-driven in terms of “what a company really needs” and not organized top-down as usually in terms of “what a company should do”. This approach enables a problem-oriented focus on the research demand of SME. We comprehend our approach as an amendment to the existing approaches with the aim to exploit innovation potential that is not reached and has therefore been lost so far. The process consists of four stages: incentive, analysis and specification, realization as well as sustainability. It covers the steps from the origination of an idea to its transformation into something useful.

The incentive stage is the first step and covers all activities concerning the first contact with a company such as impact, initiation, mutual presentation and topic screening. In this step we deal with the firms and identify their needs and innovation potential. The innovation consulting is an event we developed to use for the first meeting with a company. It is designed as a workshop and can be supplemented by the innovation lab which is mainly supposed to be used in the second step. An idea or requirement draft is generated, which marks the end of this stage and leads to the next step.

The second stage is called analysis and specification. It covers all activities concerning the analysis of innovation potential based on the company’s ideas or needs, the specification of possible topics for research activities, goals and form of collaboration as well as the assessment of technical feasibility and resources needed. Furthermore at this step we try to identify companies with related needs, problems or interests in order to create a project consortium with the aim to share costs and experience or to include skills that are not covered so far, but are essential for a successful finalization. At the end of this stage a full project plan is developed and usable for the next step. To support this stage we develop the innovation lab. The goal of the innovation lab is to provide a physical environment that will boost creativity and provide the necessary tools for the generation, discussion and assessment of innovative ideas. While large companies may have special departments dealing with R&D, within SME those activities are either located with the management or need to be done by regular departments. A creative environment can be seen as a key factor for innovation [Ek97], especially for SME, it can be helpful to use a facility that is separate from the usual working environment and is equipped with special tools. Simulation of the developed solution allows a more accurate estimation of the probability of a successful implementation.

In many cases the firms know exactly where their problems lie, but in the case of SME, they do not have the time, resources and expertise to deal with the problems in an appropriate manner. After analyzing the company’s situation, possible solutions are discussed. Thereby, the company is supposed to picture their ideal state fading of the technical practicability. After the optimal solution has been modelled, the implications, which derive from the implementation, are examined. The solution is divided into parts, which are already practicable, and parts, for which we need conduct further R&D. For the R&D activities the effort and resources needed are estimated and the project is checked for emerging costs and realistic positive achievement. If the presented solution is not practicable, the solution is redesigned with fewer requirements but without changing the objectives. At the end of this process we conceptualize a first project draft containing a problem statement and solution. The next step is to set up a detailed schedule for the R&D project containing a description of the problem statement, the identified research demand, the estimated research activities, a practicability assessment and the benefit for the company. Furthermore the project is divided into several work packages, which are split among the project partners depending on their expertise. For each work package objectives are determined, a time schedule developed and responsible persons or project partners assigned. This proceeding results in a detailed project plan with a clear assignment of duties, deadlines, work-sharing and objectives which is the basis for a cooperation agreement and further collaboration. Next, funds for the realization of the innovation project have to be assured. The easiest and straightforward way is that the financial means are provided by the participating companies themselves. The alternative is to identify matching funding programs and apply for public research funding.

The third step in the model is called realization stage. Based on the needed resources identified in the project draft, information on possible ways to implement the project are enquired. The "innovation circle" describes the collaboration between companies and research facilities. The main idea behind the innovation circles is to unite companies with related needs, problems or interests. This kind of collaboration allows sharing risks, costs and experience or allows involving further players along the value chain into the innovation process in order to include further expertise. In this stage the graduate school can be used to accomplish several tasks. The graduate school is meant to give scientific support to companies. It covers all activities with relation to research and teaching and focuses on the collaboration between students and SME. The idea behind the graduate school is to involve students in the innovation and research process whenever it is possible and gradually lead them to the objectives. Possible research topics are identified in the innovation projects and are offered as a bachelor, master or PhD thesis depending on the complexity and challenge. Students can participate in the innovation process by employing them as student research assistants or arranging internships and part-time jobs. Furthermore the project matter contributes to the day-to-day teaching by offering seminars, workshops or summer schools with current reference to the projects.

The fourth and last step is called sustainability. In this stage an assessment of the project takes place by means of defined criteria based on the goals set in the earlier stages. Furthermore, in case of a successful implementation the project is checked for further innovation potential. The focus in this stage lies on securing a broad effect of the findings.

Figure 2 shows the basic process in the model which can be modified depending on the requirements of the single innovation project.

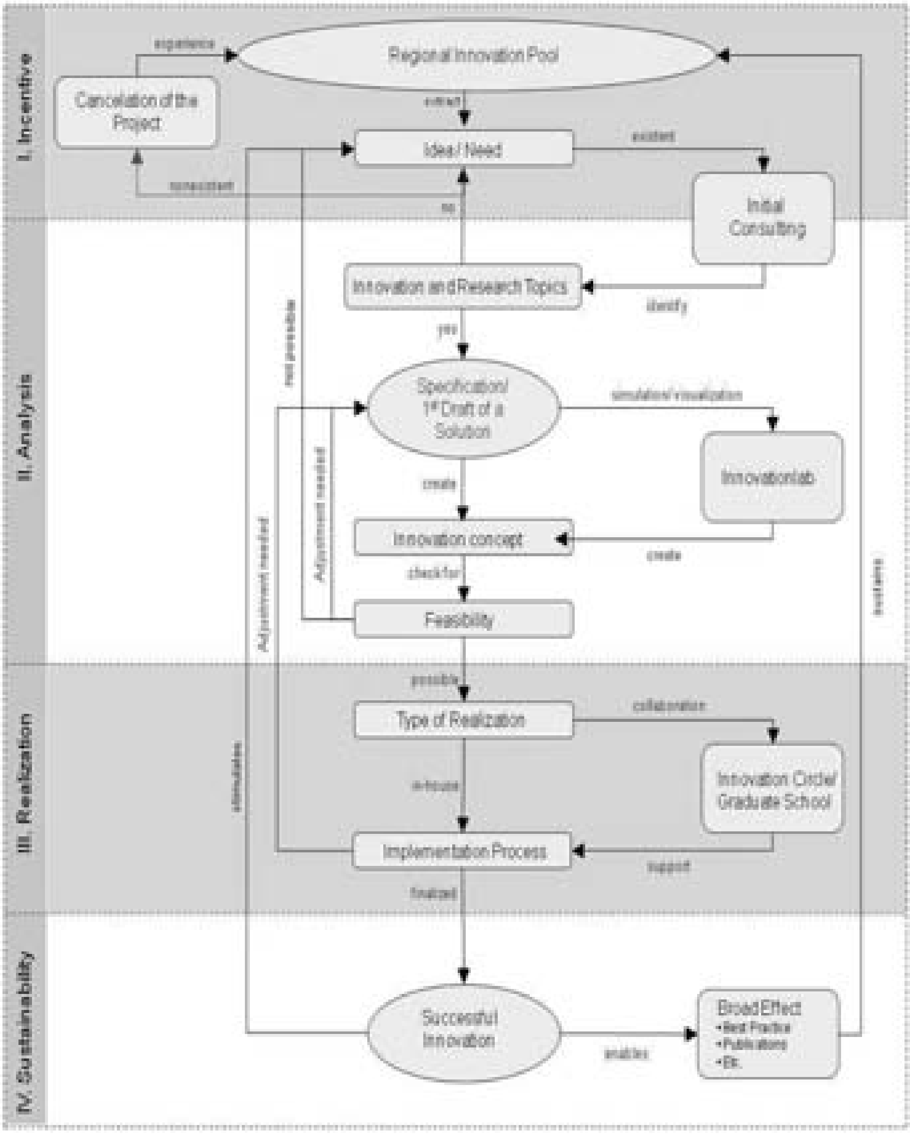

Figure 2: The Bottom-Up Innovation Process, author´s illustration.

7 Conclusion and Further Research

With over 50 innovation projects accomplished in the last three years, we can summarize that we have developed a highly appreciated approach for local SME. The methods and instruments developed for the bottom-up innovation model focus on the first two stages of the model, as these are the most interesting for inducing research activities and boosting the regional innovation potential.

Due to the practical experience documented in case studies we identify two aspects of particular interest: the "initial consulting" and "innovation lab". The initial consulting is an excellent event to establish first contact and identify innovation topics. The participating firms obtain a quick overview over their needs and potentials with hints how to activate hidden innovation possibilities and which key skills are missing and have to be acquired. SME especially value the openness of the approach and the independent consulting concerning their needs, solutions and possible partners for collaboration. The innovation lab´s main intention is to provide an environment to boost creativity but it is not limited to this. It is an excellent way to use infrastructure already existing at public research institutions. By gaining access to resources SME cannot afford on their own it is possible to reduce the disadvantage of resources shortage, a typical problem of SME. On the one hand this can be technical resources such as access to large capacity computers, virtual machines, simulation and test environments. On the other hand this can ban human resources such as knowhow in process modeling for example. Further research will be focused on this aspect, in particularly on the development of IT-supported tools to be used in the innovation lab.

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Management of Service Innovation Projects: A Case Study from a German Financial Services Provider

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Abstract: The ability to design innovative services is becoming an important capability for organizations in the 21st century. Information technology plays a major role as an enabler for a broad range of innovative services, and IT organizations need to design services in collaboration with business units to address evolving customer requirements. This paper offers an exploratory case study on the application of a design methodology at the intersection of business and IT, focusing on a German financial services provider that sought to develop new IT-based service innovations. The key finding of this case study is that while processes, methods, and tools are important for managing service design, socio-technical aspects such as context, environment, team management, and project setup also are essential for the successful design of innovative services. The current literature provides rudimentary guidance in these areas, yet a thorough description of these factors and their integration into a service design methodology has not yet been documented. Based on the findings of the case study, we suggest further investigation of the roles played by factors such as environment, team management, and project setup, as well as of the ways in which these factors can be incorporated into the creation of methods to facilitate more effective service design.

1 Introduction

Services and the service industry are becoming an increasingly important part of the 21st-century global economy [CS06]. The pursuit of a better understanding of the development of new services has given rise to a new research direction known as Service Science, Management, and Engineering. Several models exist that describe the process of service development and engineering (see for example [KS91][EO96]). These models are narrow in that they focus solely on the service development process and activities and less on the environment in which these process and activities take place. Johnson et. al. effective new service development projects are characterized by their successful use of and management of enablers such as teams and tools and propose this as an opportunity for future research [Jo00]. This case study contributes toward this research problem by providing insights from a real-world service design project in the financial industry where special attention has been given to the enabling factors such as team constellation, organizational environment and IT infrastructure.

This extension of scope in new service development is necessary because many organizations, especially those that are mature, struggle to develop innovative new services and products due to a lack of access to the resources, processes, and strategies that are needed to spark innovation [DH96] [Le01]. Several studies have suggested that overcoming this obstacle requires a different management approach capable of supporting not only incremental innovation, but also breakthrough innovations in mature organizations [Jo02] [OT04].

The design methodology that we have applied in this case study has its roots in mechanical engineering education and has been practiced for more than 40 years at a leading U.S. engineering school [Dy06] [CL09]. It is an iterative, prototyping, and customer-oriented methodology used to solve problems and develop engineering solutions [Ca07] [Sk08]; artifacts and results that have been realized using this methodology have received several innovation awards [Wi08]. Based on these successes, we have chosen to apply this methodology in a business context, and have transferred it from the mechanical engineering domain to the service design domain. The transfer of an established concept from mechanical engineering to industrialize and professionalize the service development process represents an innovative - and potentially fruitful - solution [Za06] [Wa07].

Additionally, the selection of this methodology contributes to the current discourse of “design thinking” as a new approach for the development and management of innovation [DM06] [Dy06] [Br08]. Here we define design based on the definition advanced by [Dy06], namely, as a ”[…] a systematic, intelligent process in which designers generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve clients’ objectives or users’ needs while satisfying a specified set of constraints.” Understanding this process is essential in order to improve design praxis. While the first generation of design research leveraged the field of operations research to decompose complex problems into smaller, more manageable components, the second generation of design research shifted toward understanding design as a social process [BB07]. The application of this methodology in an organization provides insight into the social context of design and innovation and contributes to the investigation of how design processes can be improved.

This case study takes as its focus a collaborative service design project undertaken by the business and IT departments of a German financial services firm. The insights gleaned from the case will contribute meaningfully to the literature on service design and innovation in organizations, and will seek to shift the research focus from the current, narrowly circumscribed view, which regards service design as a discrete activity, toward a broader, more holistic view that conceptualizes service design as one component of an organization’s overarching innovation framework.

2 Research Methodology and Case Environment

This case study is based on a four-month project within the IT organization of a large German financial services firm that took place from August to December 2009 (binding non-disclosure agreements prevent explicit mention of the firm's name). The project was initiated within the firm's IT unit to develop new IT-based services based on an initial problem definition that was devised by the business department.

The researchers in the current study apply the engineering design methodology described by [CL09] to evaluate its application and usefulness in an organizational context, following the participatory action research approach based on [SE78] [BW96] [CH98]. To do this, we have partnered with the IT unit of a major German financial services provider to create an environment that supports the service design project, as well as our research activities. The researchers acted as coaches and trainers to the design team for the application of the engineering design methodology while at the same time conducting interviews and performing surveys to gather the data necessary to address the research questions.

When designing a research methodology, one crucial decision is determining whether the study will employ a deductive, quantitative approach or an inductive, qualitative approach [HH97]. Because the current study seeks to explore a new research domain, the use of an inductive, qualitative approach such as the case study method [Ei89] [Yi94] [St99] is appropriate.

In order to achieve a high-quality case study design, it is important to consider the issues of construct validity and internal validity [Yi94]. Construct validity refers to establishing suitable operational measures for the concepts that are being studied. In this research, this was achieved by basing the study's questionnaire and analytical framework on previous theoretical and quantitative research, as shown below.

Research Area	Previous Research
Team Configuration: What personality types are necessary for a high-performance design team? What is the configuration of the team? What is the influence of the configuration on the process and project outcomes?	[Mc00] [Kr04] [Kr05] [Sk08] [Wi08]
Perception: How are the specific aspects of an innovation project (insecurities, creativity, ambiguity, etc.) perceived within the corporate environment?	[Ca03] [Dy06]
Success Factors: Which factors within the team and the organization are necessary for a successful project flow and outcome?	[SC99] [Jo00]
Operational Challenges: Which factors within the organization negatively impact the performance of the design team?	[DH96] [KS96] [Le01] [OT04]

Table 1: Literature research on relevant research areas

Internal validity refers to the reliability of a study and whether the variables that have been chosen are sufficient to describe and explain the topic under investigation. To ensure internal validity, we have conducted semi-structured interviews with each member of the design team, as well as with other key community members, after each major project milestone. Altogether, 38 interviews were conducted, recorded, transcribed, and analyzed (20 with the design team and 18 with community members). Second, the design team answered a weekly questionnaire that sought to observe certain parameters and characteristics of the design project; a total of 72 questionnaires were completed by the four design team members over the 18-week duration of the project. Additionally, pertinent observations made by the trainer were recorded in a project diary that was updated on a weekly basis.

3 Service Design at the Intersection of Business and IT

3.1 Prerequisites and Environment

In order to foster an innovation-friendly environment within the case organization, several prerequisites had to be established. Then nature of these prerequisites came from coaches who have previously applied this method in the academic environment and who were able to use their knowledge to recreate a similar environment within the organization.

Defining the Project Proposal

The initial project proposal was based on a solely technical premise, and aimed to developed applications for Microsoft Surface computers. Even though an existing application had already been transferred to this computing platform, the firm's business departments were looking for new approaches to engage customers with this technology. Therefore, the project proposal was shifted from one with a wholly technical perspective toward a broader strategic business perspective.

One challenge for financial services providers is the increasingly prevalent use of self-service technology, which reduces the number of personal interactions between employees and customers. Despite the convenience that self-service options offer, employee-mediated interactions are important to allow employees to identify customer needs and provide a customized, individualized financial advisory experience. Based on this challenge, the following problem statement was defined in the project proposal:

> *How can we stimulate customer interest, allow customers to signal their interest, and then create a unique, customized personal financial advisory experience?*

This problem statement shifted the focus from the technical and business aspects of the project toward the needs and interest of the customer or end-user, creating the basis for a solution that could incorporate both technical improvements and heightened service quality and responsiveness.

Team Selection

The design team consisted of four interns who were recruited using the existing internship recruitment processes in place in the organization. This process is relevant for two reasons. First, the students had no previous design experience or financial services industry experience. Second, the selection of students was based primarily on the firm's existing recruitment guidelines and did not incorporate any specific aspects that have proven to be relevant in the effective creation of design teams.

One such consideration is team diversity. It has been shown that highly diverse teams consistently achieve superior outcomes [Le98] [Wi08]. 'Teamology,' a methodology based on the Myers-Briggs personality test, helps to identify the personality traits and cognitive modes of individuals, and, by following an algorithm, to select members and form teams comprising a broad range of personality types [Wi08].

Table 2 shows the dominant cognitive modes that were present in the design team, according to the Teamology model. It should be noted that while the team incorporates each one of these cognitive modes, no single mode is particularly strongly represented; one dimension (Introverted Thinking/Analysis) is almost completely absent.

	ES	**EN**	**ET**	**EF**	**IS**	**IN**	**IT**	**IF**
	Extraverted Sensing	Extraverted Intuition	Extraverted Thinking	Extraverted Feeling	Introverted Sensing	Introverted Intuition	Introverted Thinking	Introverted Feeling
	Experiment	Ideation	Organization	Community	Knowledge	Imagination	Analysis	Evaluation
Team Member 1	0	5	0	7	0	3	1	0
Team Member 2	0	0	0	0	0	8	0	4
Team Member 3	3	3	3	0	0	0	0	1
Team Member 4	0	0	8	0	14	2	0	8

Table 2: Cognitive modes of design team based on MBTI; maximum score is 20

Project Environment

The various project stakeholders and the relationships between them are depicted in the following illustration:

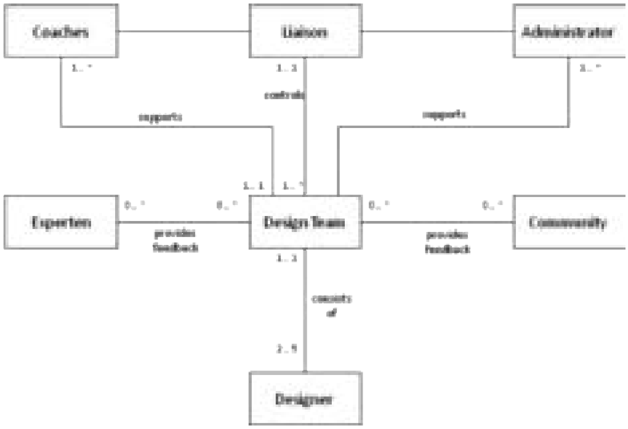

Figure 1: Project Structure and Roles

The design team consisted of four recent graduates who were coached by method trainers to apply the design thinking methodology and to develop solutions to the defined business problem. The trainers also facilitated the dissemination of new concepts and techniques (i.e., ethnography, brainstorming, prototyping, user testing, and problem reframing), since the team members had not previously employed these approaches. The liaison, who functioned as the chief decision-maker that steered the project team and defined the problem statement, also provided feedback about the individual prototypes. The stakeholder group representatives included several employees of the financial services firm with expert knowledge in certain domains (i.e., software development, hardware, market research). Another group of employees formed the largest stakeholder group, known as 'the community,' which provided feedback on the developed prototypes at major project milestones through semi-structured questionnaires.

Infrastructure

Each member of the design team was issued a corporate laptop computer and granted access to the IT resources that are available to every employee in the organization (e.g., remote access, printing, etc.). Additionally, the team was able to use a Microsoft Sharepoint Server for collaboration, as well as an Atlassian Confluence used as a team wiki for documenting the design process. In addition to this IT infrastructure, the team was given office space in the corporate "innovation lab," which was a prototype for a future work environment designed to support collaboration.

3.2 Design Process

This chapter describes the actual design process followed by the team. Based on the engineering design method defined by [CL09], the core design cycle forms the base of the iterative design process and consists of five stages. The fundamental stages of the core design cycle are based on the Innovation process as defined by [Ow98] and adapted by [BB07], and are shown in

Figure 2.

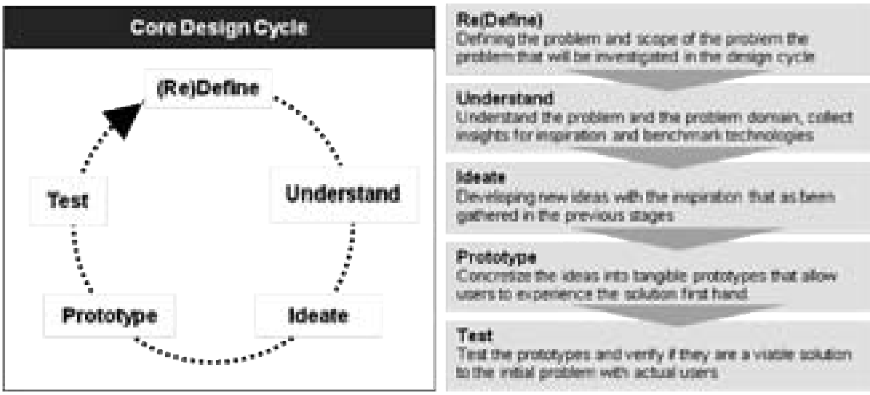

Figure 2: Core Design Cycle and Process Steps in the Core Design Cycle

This design circle is performed continuously during the design process, with a scope that shifts from user research (Understand) and idea generation (Ideate) in the early stages toward prototyping (Prototype) and user testing (Test) in the later stages. The early iterations emphasize divergent questioning, in which the “questioner intends to disclose the alternative known answers and to generate unknown possible ones” [Dy06]. This leads to divergent thinking, where the questioner moves from facts to possibilities with generative design questions. The later prototypes are converging where the questioner asks deep reasoning questions to converge by revealing concrete facts [Dy06]. One essential principle of this approach is to preserve ambiguity during the design process, quelling the tendency to eliminate it and converge toward a particular solution [Dy06]. The core design cycle, as well as the different prototype milestones, are shown in Figure 3, along with the names assigned chronologically to the individual prototypes.

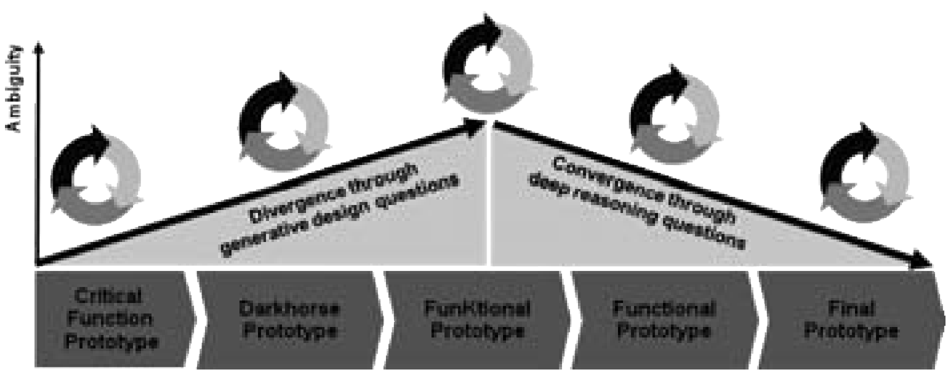

Figure 3: Design Process and Prototype Milestones

In order to elucidate the actual design process and the prototypes that were developed, the following sections explain the prototype milestones in greater detail and provide examples about the interim solutions that were considered over the course of the project.

Critical Function Prototype

The aim of this phase is to better understand the given problem statement and the overall problem domain, as well as to identify the critical functional requirements of a potential solution. Tasks in this stage include seeking to understand customers and their needs and behavior, as well as attempting to understand and screen new technologies and business models as possible sources for idea generation. These activities form the major components of the first stage of the design process and based on the insights gathered in this stage a set of prototypes is implemented to provide solutions to the identified critical functions.

Darkhorse Prototype

After the problem has been addressed for the first time in the critical functional prototype phase, the second prototype phase, the so-called darkhorse phase, allows the design team to restart their approach and pursue a different direction. The motivation for this is twofold. First, it allows the team to address the problem from a different perspective, allowing a broader range of potential solutions to emerge. Second, the darkhorse stage allows design teams to experiment with high-risk solutions that may have been considered too risky in the first phase, but could ultimately provide a breakthrough solution to the problem, as has been the case in countless projects in the academic environment.

FunKtional Prototype

The FunKtional Prototype aims to integrate and combine the different prototypes that have been developed in the previous stage into a coherent, holistic concept or vision statement that acts as the point of reference for the later stages of the design process. This phase also consolidates the customer feedback from the previous stages to ensure that the defined vision meets customer requirements.

Functional Prototype

The Functional Prototype phase marks the milestone when the team defines the scope of the final solution that will be delivered at the end of the project. This prototype is also essential for the internal customer, because at this point of maximum diversification, it is possible to define the cone in which the team should converge.

Final Prototype

The Final Prototype in most cases consists of several other previous prototypes that ultimately are integrated into a coherent concept. The sequential stages of the prototype for the interactive financial advisory services are shown in Figure 4.

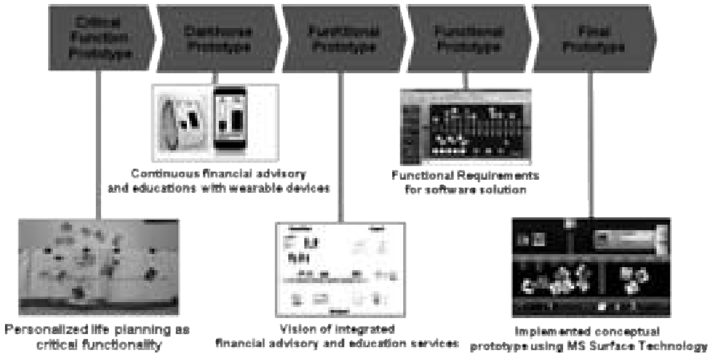

Figure 4: Selection of actual prototypes of the design process

4 Findings

The following sections offer the findings and observations made during the study.

4.1 Team Configuration

Team Member Selection based on Personality Tests not permitted by Law

In order to achieve optimal team diversity, it is beneficial to consider the personality traits of potential team members. However, labor laws in Germany and many other countries do not permit information to be collected about employees that could be used in a discriminatory manner, and Teamology personality assessments could be construed to fall into this category. The information about the interns could only be collected by ensuring the anonymity of the individual team members. Therefore, in some organizations, selecting team members based on Teamology or any other method that identifies individual traits or characteristics is not possible.

Lack of Project Leader puts full Responsibility on the Design Team

Since the methodology did not allow for the designation of a team leader or project manager, the team's decisions had to be determined through lengthy discussions in which all four team members debated each course of action. To outsiders, this approach appeared to be inefficient and unnecessarily lengthy, but team members reported that the extensive discussion helped them to identify the best potential solutions. Furthermore, we observed that this process resulted in greater consensus and support of the team's final decisions, a finding that was confirmed in the interviews and that may have important implications for coaches or managers supporting team projects.

Existing Recruitment Processes tend to eliminate Candidates needed for a diverse Team

To some extent, the interns who participated in the project shared similar personality traits, educations, and backgrounds, with the notable exception of the mechanical engineering student who represented something of an anomaly; existing recruitment processes in place at the firm render it difficult to assemble a truly diverse team. During the project, it was observed that the team experienced difficulty generating truly radical ideas and concepts; instead, they hewed to a more conservative approach to problem solving. This may be attributed to the fact that none of the team members possessed dominant extroverted, intuitive and imaginative personalities. Additionally significant coaching was necessary to induce the team members to conduct user research and to perform user testing in various public locations.

4.2 Perception

Different understandings of innovative Environments

One salient observation made during this project is that different stakeholders in the organization harbored a wide range of perceptions about what it means to work in a creative, innovative environment. In this project, it was observed that the once-orderly office devolved into a somewhat chaotic environment full of sticky notes for brainstorming and toys and tools for prototyping. If certain stakeholders are irritated by this approach it is the responsibility of the bridgehead to communicate the characteristics of the design methodology and ensure the support of this stakeholder. Otherwise the support for fostering such an environment could erode and negative attitudes can emerge.

Embracing radical new Ideas

Typically, the darkhorse prototype stage allows the design team to explore breakthrough ideas and radical solutions without being beholden to traditional strictures, norms, or paradigms. However, we observed that this design team was hesitant to push the boundaries of their imaginations too far, due in part to the fear that their ideas might be considered too radical or visionary. Significant encouragement from the trainers was necessary to ensure that the team afforded sufficient consideration solutions that broke with existing assumptions.

4.3 Success Factors

Integration of Business Departments

A clearly defined role for the project owner, the liaison, is an important project success factor. From defining the initial problem, to guiding the team through each phase of the design process, to ensuring that prototypes satisfy the organization’s needs, the input of the project owner can significantly influence the outcome of the design process. The presence of a business-oriented project owner proved beneficial in this project; in contrast to the unwieldy “steering committee” approach used in many collaborations between business units and IT departments, the strong leadership influence of the business unit in this project helped to ensure that the final product was well-aligned with the organization’s strategic goals.

Prototypes create a common Language between different Stakeholders

Most work teams' members have been drawn a variety of disciplines and backgrounds. This is especially true at the intersection of business and IT. Although there are many advantages associated with diverse teams, interdisciplinary communication can sometimes be a problem. In this study, it was observed that tangible prototypes create a common language and provide the basis for improved communication between different stakeholders. This was particularly evident when delegations from other countries or cultures visited the innovation lab - the tangible prototypes provided a common touchstone for discussion.

Project Rooms

Although it may seem to be an incidental factor, the physical environment in which collaborative innovation takes place can beneficially impact project outcomes. The "innovation lab" that served as the backdrop for this project seemed to play a significant role in fostering a successful project outcome. The team's ability to modify the setting to facilitate innovation, creative discovery, and collaboration also proved to be important. The team also used the room to display the prototypes, ensuring that visitors to the space could view the models and offer feedback, even on short notice.

Bridgehead

A major part of the success of this project can be attributed to the activities of the administrative bridgehead who acted as the connector between the design team and the rest of the organization. The activities of the bridgehead included the facilitation and preparation of infrastructure, as well as the management of daily operations and organizational communications for the design team. However, budget management proved to be a formidable challenge for the bridgehead; a dedicated budget was not allotted to the design project, so many procurement processes were delayed; in some instances, project team members and trainers were forced to cover expenses out-of-pocket.

4.4 Operational Challenges

Traditional corporate IT Infrastructure not sufficient for radical Collaboration

The laptop computers provided to the project team were equipped with the standard IT applications available to every employee in the organization. However, it soon became clear that these computers were not sufficient to perform some of the tasks in this project (e.g., photo editing, video editing, animation creation). In addition, the available document editing and file sharing tools did not support the radical collaboration work style that the design team was called upon to use. This lead to a situation in which the design team members had to use their personal laptop computers, circumventing the corporate IT system through ad-hoc wireless networks to quickly share large files and use software that is not included in the organizations application portfolio.

Concerns regarding wrong Focus or Lack of Focus

Community members who had a close relationship to the design team sometimes expressed concerns about the team's focus, albeit indirectly and often without providing specific examples. Nevertheless, by dint of the questions, comments, and discussions between the bridgehead and members of the community, it was revealed that some regarded the team as being insufficiently goal oriented. However, it is important to note that inspiration can come from any source and in many instances, innovation proceeds along a lateral, associative, and/or non-linear course. If a design team is dissuaded from exploring seemingly unrelated areas, the essence of an open innovation culture can be destroyed.

Breakthrough Innovation vs. Meeting predefined Goals

One area that has been subject of much discussion in recent years is the trade-off between achieving pre-defined business goals and clearing the path to allow radical new innovations to emerge. In the case project, several concepts and prototypes were discarded because the liaison stated that while they were important, they did not necessarily contribute toward the organization's stated objectives. These ideas have not been pursued further, despite the fact that with additional effort, they may have evolved into radically new concepts and service offerings.

5 Discussion and Conclusions

From an organizational perspective, the project has been deemed a success, having achieved an outcome that exceeded initial expectations. Based on the result of this project, management has decided to pursue additional projects using the design-thinking approach, with the goal of building up the necessary knowledge to oversee similar undertakings within the organization; this indicates that the design-thinking approach has the potential to bring significant value to an organization seeking to increase its innovative capacity.

The findings need to be discussed in relation to service design in an organizational context. Past research has often focused on the process, activities, and tools used to design new services and research opportunities to explore enabling factors for service innovation projects have been defined. The current results indicate that the context and environment in which these services are designed are as important as the process itself. Therefore, the scope of service design management should be broadened to include more than just processes, activities, and roles. The case study has shown that while the activities of user research, ideation, and prototyping are important, breakthrough innovations can only emerge by creating the right environment, assembling a well-composed design team, and motivating and leading the design team according to protocols designed to facilitate optimal performance. Traditional project management approaches might not be suitable to create the environment that enables a successful new service development project.

Since the environment in which innovation occurs is of high importance, the framework and methods employed in service design and service design management need to address social, physical, and other environmental factors that foster innovation. This is especially important when a large and mature organization is seeking to pursue innovation, due to the other factors that tend to hinder radical breakthroughs in such an environment. One future research question should center on whether this should be done in a top-down manner by defining management concepts for service design, or in a bottom-up manner by extending existing service design/project management models and frameworks to address environmental and other factors.

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Service-oriented Supply Chain Event Management – A Case Study from the Fashion Industry

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Abstract: Service-oriented architectures (SOA) are spreading in many organizations and aim at enhancing efficiency, agility, and productivity of business processes. Standardization and modularity enable the networking of application-based business functionalities especially in inter-organizational settings. This research analyzes the potentials of SOA in the domain of supply chain management (SCM), in particular supply chain event management (SCEM). Among the findings is that SCEM applications focus on specific functionalities and that integration of multiple application is required to support the entire SCEM process. Based on a systematic methodology, the key services required for SCEM are identified also using a case study from the fashion industry.

1 Introduction

Due to its globalized supply chain structures, a large variety in SKU[1]s, short product life cycles, the necessity to react quickly to customer demands as well as volatile business relationships, the fashion industry belongs to one of the most challenging application areas for supply chain management [Bru03, p. 2 ff.; Tro08, p. 22]. One possible concept that has been suggested to cope with this logistical complexity is SCEM. In recent years, various authors like [Wie01; Nis02; Ott03; Bod05; Heu06; Liu07; Mue09] have analyzed the concept of SCEM from different perspectives such as benefits, goals, definition, functionality, modelling, application, need, configuration, and architecture. This research paper was motivated by two hypotheses:

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1 SKU (Stock Keeping Unit). In terms of the fashion industry a unique combination of article/ style/ colour/ size.

(A) To date, there has been no contribution addressing SOA in the context of SCEM (though [Spe04] go into the application of web services in general). Due to its flexibility and efficiency, SOA probably is more appropriate than current SCEM architectures.

(B) SOA requires the link to application domains, i. e. services need to be specific to business processes and industries as "… each service is assigned its own functional context and is comprised of a set of capabilities related to this context." [Erl08, p. 39] Thus, a contribution about service-orientation in the area of SCEM in a specific industry seems appropriate.

The remainder of this paper is structured as follows: Chapter 2 provides an overview of SCEM and SOA as well as presents both research questions and methodology. Chapter 3 comprises a survey of current SCEM architectures regarding their functional coverage and component distribution. Chapter 4 starts with the introduction of a systematic service identification methodology, which then is applied to the definition of SCEM-related services using the example of the fashion industry. Based on that, their distribution as well as potential users and providers are discussed. The paper closes with a summary and an outlook on future research issues.

2 Basic Concepts and Research Outline

2.1 Supply Chain Event Management

Supply chain management (SCM) aims at improving the allocation, management and control of logistic resources. One key concept within SCM is SCEM which may be characterized as an approach to achieve inter-organizational visibility over logistical processes enabling companies to detect critical exceptions in their supply chains in time. Thus, measures against those "events" can be taken proactively before they have negative impact on given business plans [Nis02, p. 477; Heu06, p. 19].

Most authors agree on the perception that SCEM encompasses five core functionalities (see Figure 1) [Wie01, p. 66; Heu06 p. 22 ff.; Bod05, p. 58, e. g.], which are illustrated by means of the following example: *(1) Monitor:* Evaluating process tracking data, a delay in material delivery with a manufacturer is detected. *(2) Notify:* This information, along with context data, is reported to the process owner (procurement manager, e. g.). *(3) Simulate:* For decision support, the process owner is provided with an indication of the impact (estimated missed deadline, e. g.) as well as available action alternatives (place order with another supplier; change mode of transportation, e. g.) to handle the delay. *(4) Control:* Having chosen one of the options, the process owner is supported in accomplishing it (place/ change/ cancel material or transfer order, respectively). *(5) Measure:* The last function bridges the gap between SCEM and SCM by analyzing all gathered data (number/ time/ locality of event occurrences, chosen action alternatives, e. g.), thus enabling companies to identify certain patterns related to the causes of events (e. g., supply chain bottlenecks) in order to optimize their supply chain structures.

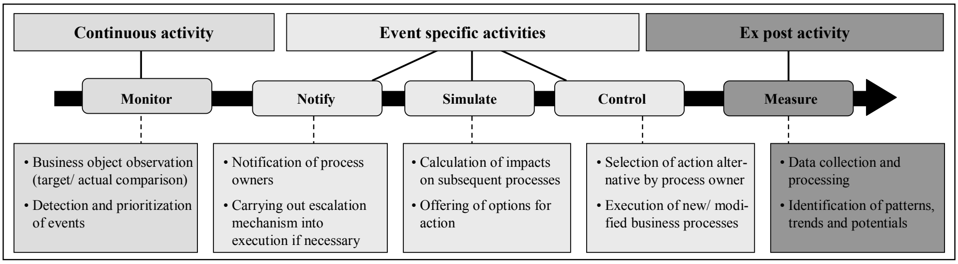

Figure 1: Functionalities of Supply Chain Event Management

2.2 Elements of Service-oriented Architectures

According to [Erl08, p. 39], SOA is based on the design paradigm of service-orientation, which comprises a specific set of design principles, whereas the most fundamental unit of service-oriented solution logic is the service. Furthermore, SOA "… establishes an architectural model that aims to enhance the efficiency, agility, and productivity of an enterprise by positioning services as the primary means through which solution logic is represented in support of the realization of strategic goals associated with service-oriented computing." [Erl08, p.38] As stated by [Alt09, p. 106], the three major elements of any SOA are services, service repository, and (enterprise) service bus.

(a) Services: Services can be characterized as well-defined, self-contained, and reusable modules providing specific functionalities which are independently deployable and have a standardized interface. According to [Pap07, p. 390], the most popular type of services available are those utilizing web service standards, i. e. Web Service Description Language (WSDL), Simple Object Access Protocol (SOAP), and Universal Description, Discovery and Integration (UDDI). [Koh09] differentiate business-, application-, and IT-services, whereas the first "represent functionality of a specific business activity and transaction (…) [, the second] independently usable and elaborately specified components (…) [whereas the last stand for] encapsulate[d] technical capabilities independent of any business domain" [Koh09, p. 204]. An alternative taxonomy is provided by [Pap07, p. 406] who distinguish basic, composite, and managed services.

(b) Service repositories and directories: A service repository mainly comprises the technical information about the service (e. g. its address and WSDL description) and "… acts as the central modelling and design environment" [Alt10, p. 5]. Service directories (or registries) "… allow service providers to register new services and service consumers to search for and locate services (…) [in order to] match buyers and sellers, to facilitate transactions and to provide the institutional infrastructure for business." [Leg09, p. 70] According to [Alt10, p. 4] two directions can be reported from research on SOA projects in practice: maintaining and establishing individual service repositories as well as utilizing inter-organizational service directories.

(c) Enterprise Service Bus (ESB): An ESB "… is an open, standards-based message bus designed to enable the implementation, deployment, and management of SOA based applications." [Alt10, p. 3] It can also be termed as the integration platform for a SOA as it is designed "… to provide interoperability between large-grained application and other components via standards-based adapters and interfaces." [Pap07, p. 393] Well-known providers of ESB solutions are *Sun Microsystems* ("Open ESB"), *IBM* ("WebSphere Enterprise Service Bus"), *Microsoft* ("Biztalk Server"), and *Oracle* ("Oracle ESB"), respectively.

2.3 Research Questions and Methodology

In conjunction with the above hypotheses, the following research questions (RQ) were set up:

RQ1: Which SCEM-related functionalities are included in current SCEM architectures?

RQ2: How can SCEM-related functional requirements be defined as services?

RQ3: How can SCEM-related services be distributed in a fashion industry network?

For answering the above research questions a literature analysis along with a case study approach was undertaken. Case studies are the appropriate strategy when "how" and "why" research questions are given priority, "… and when the focus is on a contemporary phenomenon within some real-life context." [YIN84, p. 13] For our purpose, a holistic multi-case study in the fashion industry with seven German fashion companies was conducted, whereas small (Maerz Muenchen, René Lezard, Van laack), medium (Gardeur, Seidensticker) as well as large (Galeria Kaufhof, Gerry Weber) enterprises have been included in order to achieve a characteristic, though not representative sample.

3 SCEM Architectures to Date

3.1 Functional Coverage

In the course of the literature research seven authors were identified who have dealt with possible SCEM architectures by now. Four of them regard SCEM and its corresponding functions as introduced in chapter 2 [Wie01; Nis02; Bod05; Kur05]. The dissenting opinions of the remaining authors can be explained as follows: [Ott03] contemplates SCEM out of three perspectives (as a management concept, software solution, and software component). [Spe04] term their approach "disruption management and controlling", though it follows the same idea as SCEM. Finally, [Tri09] just refer to EPCIS[2]-related architectural components.

The left side of Table 1 shows the coverage of SCEM-specific functionalities. A filled circle indicates that the architecture explicitly addresses the respective functionality,

2 EPCIS (Electronic Product Code Information Services)

whereas an empty circle signifies that it is either not addressed or not specified. Interestingly, even though (mostly) naming all SCEM-specific functionalities in their contributions, none of the authors actually consider all five functions in their proposed architectures. For instance, [Nis02, p. 478] claims that monitoring and notifying represent the most innovative elements of SCEM while referring to existing SCM planning tools and data warehouse solutions which were already capable of covering the three remaining functionalities. A similar view can also be found in the contribution of [Kur05, p. 23]. Regarding RQ1, available SCEM architectures do not cover SCEM-related functions to 100%. In most cases, they just focus on *monitor*, *notify*, and *measure*, which probably is due to the fact that the latter are less innovative as they are realizable through various and already available means. With regard to *simulate* and *control*, the analysis discloses a research gap. SOA could be the way to close this gap by providing the missing functionalities through utilizing (external) services.

3.2 Components and their Distribution

The following architectural components were named repeatedly by the above authors in support of the functional range of SCEM: Enterprise resource planning (ERP) systems, advanced planning systems, tracking & tracing (T&T) systems, sensor systems, transport management systems (TMS), EPCIS repositories, web server/ clients, short message service (SMS) server/ clients, e-mail server/ clients, data bases, and data warehouses. However, the central component of SCEM systems is the “SCEM Engine” [Wie02, p. 66; Nis02, p. 478; Ott03, p. 9], which itself consists of several sub-components: an *event processor* for input data analysis (matching with predefined event profiles, e. g.), a *rule processor* for triggering activities based on assigned rules, an *alert manager* for communicating with process owners and applications and a *configurator* for defining and maintaining event profiles and rules (if-then-else statements, e. g.).

Authors	Focus	Coverage of SCEM functionalities (●...yes, ○...no/ n. s.)					Distribution of architectural components (l...local, c...central)					
		Monitor	Notify	Simulate	Control	Measure	SCEM Engine	Monitor	Notify	Simulate	Control	Measure
[Wie01]	SCEM with mySAP SCM	●	○	○	○	○	l	l	-	-	-	-
[Nis02]	Conceptual introduction to SCEM	●	●	○	○	●	l	l/c	l/c	-	-	l
[Ott03]	SCEM as management concept, software solution and component	●	●	○	○	●	l	l/c	l/c	-	-	l
[Spe04]	Disruption management with web services	●	●	●	○	●	l	l/c	l/c	l/c	-	l
[Bod05]	Proactive SCEM with agents	●	●	○	○	○	l	l/c	l/c	-	-	-
[Kur05]	SCEM with mobile/ agent technology	●	●	○	○	○	l	l/c	l/c	-	-	-
[Tri09]	EPCIS-based SCEM system architecture comparison	●	○	○	○	○	l	l/c	-	-	-	-

Table 1: Evaluation of existing SCEM architectures

The findings concerning the distribution of the aforementioned components are as follows: In case of the SCEM Engine as well as the components enabling the *measure* function, the respective authors indicate a local implementation by common consent. As for the components regarding *monitor* and *notify* almost all authors see both local and centralized components fit to accomplish the required processes. With regard to *simulate* and *control*, none of them but [Spe04], who makes use of local as well as centralized components for the *simulate* function, explicitly suggest any components. Thus, no conclusion regarding their distribution can be made. The results are shown in detail in the right columns of Table 1.

4 Identification and Distribution of SCEM-related Services

Generally, in a SOA environment, the function of the *SCEM Engine* instead of being part of a monolithic SCEM application (see chapter 3.2) can be covered by the ESB (see chapter 2.2), which invokes the SCEM-related services defined in the following. This requires the transformation of event profiles and corresponding rules into conditions and workflows which are defined and maintained through the ESB user interface.

4.1 Service Identification Framework

For the definition of SCEM-related services, the service identification framework by [Alt09/ Koh09] was used, which in turn is based on the Business Engineering approach by [Oes95]. It pursues a "… hybrid service design capturing business-oriented and technical-driven service identification" [Koh09, p. 203] as neither technical-driven (bottom-up) nor business-driven (top-down) service modeling is sufficient on its own. Service identification according to the top-down approach "…is based upon business processes or business events while applying wide-spread design principles of SOA (…) [whereas] bottom-up refers to service modeling based upon the analysis of existing applications and their IS functionality (…) focusing on consolidating and rationalizing access to IS functionality by using services." [Koh09, p. 204] To answer RQ2, the framework was adapted as follows:

(1) Analysis of supply networks of the fashion industry, encompassing their business models, structures, major processes, roles, and dependencies.

(2) Identification of required SCEM-related functionalities and – based on that – corresponding services (in identifiying conponents that can encapsulate those functionalities as services or by refering to already available services) [chapter 4.2].

(3) Determination of potential service providers and users, including the actual or presumable origin and level of standardization of the concerned services [chapter 4.3].

Regarding step (1), research findings by [Bru03] were utilized, who – based on an empirical study – identified four supply chain types for the apparel industry [Bru03, p. 36 ff.].

4.2 SCEM-related Services

As a basis for defining SCEM-related key services (listed in the left column of Table 2), the ten supply chain incidents most frequently mentioned by the case study companies were applied: short-term change in design, delay in lab dip process, capacity constraint, machine breakdown, sudden employee leave, force majeure (thunderstorm, earthquake, e. g.), too late arrival of fabrics/ trimmings, missing customs documents, lost of maritime container, and traffic jam.

Monitoring: As for input data, the following sources were considered to be appropriate for the above mentioned events: T&T data (provided, for instance, by DHL's service *TrackIT*); EPCIS data retrievable from EPCIS repositories "…which are hosted at each supply chain participant (…) [and provide] web services (…) that can be accessed to retrieve the EPC-related data" [Tri09, p. 494]; intra- and inter-company process tracking data which either can be made available via proprietary query services (as most of the case study companies accomplish that with excel-based workflow applications), via services provided by ERP systems (*SAP*, e. g.), or via web-based platforms (*OSCA*, *TXTCHAIN*, e. g.). For target/actual comparison, target data (ideally, object identity, place, time, quantity, and costs as they correspond to the 5 "R's" of Logistics) is to be retrieved from the business objects (i. e., production/ transfer/ customer order; schedules) stored in ERP systems, TMS or local data bases. Since some events like force majeure and strikes cannot be perceived by the aforementioned means, it is advisable to integrate services like *Metro Monitor* or *Google alerts* supplying news data about severe incidents in relevant countries (exceptional weather, traffic, or political conditions), too.

Notification: As soon as an incident has been detected the process owner is to be determined. This, for instance, can be accomplished by a service querying an authorisation directory. For alerting the person in charge, all communication media in use with the organization shall be supported. Relating to the case study companies, e-mail and SMS (for mobile phones without e-mail functionality) were named as communication media to be supported. Since firms usually operate their own e-mail server, they can specify company-specific e-mail services. As for SMS alerts, numerous web service offers (*top concepts* or *StrikeIron,* e. g.) are available. One way to realize an escalation mechanism could be in composing a service that checks if a person in question is in office (by querying the time management database for clock in/ out data, e. g.) with services that query the contact data of representatives and forward the alert message.

Simulation: As for the evaluation of impacts on subsequent processes, an indication about the extent to which due dates (customer delivery date, e. g.) are at risk was considered to be sufficient by the case study companies. To this end, services can be employed which calculate updated due dates from input data gathered by the monitoring services and average lead times queried, for instance, from a data warehouse. With regard to the generation of action alternatives it was asked for reliable real-time information (free capacities, material on stock, freight tariffs, etc.) from the supply chain partners. As for this, the latter ones have to offer web services encapsulating the relevant functionalities (*SAP*'s enterprise service *Query Material In*, e. g.) of their ERP systems or TMS. However, with the exception of inventory status services similar to *Amazon*'s *Inventory Service*, there are no such web services actually offered to date. As an interim solution, a company can load empiric lead times along with schedules and freight tariffs in a database which can be queried by a local service.

Controlling: As for supporting the operator in accomplishing the selected option(s), again, some web services concerning inter-company activities (such as enquiries for placing/ modifying/ cancelling of production, transport, delivery, and customer orders, e. g.) necessary to this end are not yet available. However, the opportunity to encapsulate those TMS/ ERP/ advanced planning systems functions as services exists for those fashion companies operating own production plants, warehouses or means of transportation, which holds true for 5 out of 7 of the case study companies. Apart from this, certain event types have no need for IT support as their handling is possible just manually and a notification of the persons in charge (for speeding up design process, customs declaration, e. g.) was considered to be adequate.

Measuring: Since all case study companies have reporting solutions available (either proprietary ones or standard products such as *MicroStrategy* and *Business Objects*), the most convenient way to accomplish the last of five SCEM functionalities is to apply an archiving service which continuously transfers and stores event data in a specific database as well as ETL (Extract, Transform, Load) and data mining services which provide the process owners with regular reports containing key figures such as supply chain partner performance ratings (number of event types, e. g.), fill rates (in terms of production, transfer, and customer orders, e. g.) as well as trends and patterns (regarding place, frequency and probability of critical incidents) in order to get indications for the optimization of supply chain performance in the middle and long term.

4.3 Distribution, Potential Providers and Users Of SCEM-related Services

As a basis for presenting our conclusions regarding the distribution of SCEM-related services, the 2x2 matrix for classifying service repositories and registries by [Alt10, p. 7] is used (see Table 2). It is extended in such a way that it not only distinguishes the origin of services and their level of standardization, but also assigns the identified services to potential providers and users. Nevertheless, the table just can provide an indication since our analysis was based on a non-representative sample. Thus, numerous other SCEM-related (web) services are possible, too.

Cluster	*Services*	*Potential service provider(s)*	*Potential service user(s)*	*Origin of services*			
				Centralized		*Decentralized*	
				Standards			
				global	*local*	*global*	*local*
Monitor	Get T&T data	FWD	LSP/FC/CU	x		x	
	Get EPCIS data	INS/MR/FWD/LSP/CU	FWD/LSP/FC/CU	x		x	
	Get process tracking data	INS/MR/FWD/LSP/FC	FC			x	x
	Get target data	CU/FC	FC				x
	Get news data	OTH	FC	x	x		
Notify	Get contact details	FC	FC				x
	E-mail alerting	FC/OTH	FC			x	x
	SMS alerting	OTH	FC	x		x	
	Absence check	FC	FC				x
Simulate	Update due dates	FC	FC				x
	Get available inventory	INS/MR	MR/FC			x	x
	Get production tender	MR	FC				x
	Get transportation tender	FWD	FWD/FC			x	x
	Get empiric/ target data	FC	FC				x
	Create action alternatives	FC	FC				x
Control	Place/ change/ cancel item/ material order	INS	INS/MR/FC			x	x
	Do., for production order	MR/FC	MR/FC			x	x
	Do., for transfer order	FWD/FC	FWD/FC			x	x
	Do., for delivery order	LSP/FC	LSP/FC				
	Enquire change/ cancellation of customer	CU/FC	FC			x	x
Measure	Data archiving	FC	FC				x
	ETL	FC	FC				x
	Pattern/ trend analysis	FC	FC				x
	Report generation	FC	FC				x
Legend: INS … ingredients supplier | MR … manufacturer | FWD … forwarder | LSP … logistics service provider | FC … fashion company | CU … customers (retail/ wholesale) | OTH … others							

Table 2: Classification of selected SCEM-related key services

After all, event types and the respective business processes to be supported are always specific to the application domain. Addressing RQ3, both global and local providers for services related to *monitor* and *notify* were identified, whereas services for the remaining functionalities can either be provided by the fashion company itself or their supply chain partners. Only in case of the services concerning *measure* there seems to be limited potential for service-orientation as the identified services tend to be too company-specific.

5 Conclusion and Future Research

This research was motivated by two major issues: first, SCEM architectures never have been analyzed from a service-oriented point of view; second, to enhance service-orientation in the area of SCEM and the fashion industry. After introducing basic SCEM and SOA concepts, present SCEM architectures were analyzed with regard to their functional coverage and component distribution Thereby, a research gap concerning the functionalities *simulate* and *control* was disclosed. In order to identify SCEM-related services, a modified service-identification framework was applied, whereas findings from a multi-case study in the fashion industry were utilized. It became clear that SCEM systems are characterized by a heterogeneous range of functions which – encapsulated as services – can be used by various supply chain participants and provided by multiple service providers as well as available components. In doing so, SOA was discovered to be applicable in order to cover all SCEM-related functionalities.

Various interesting subjects for future research emerge: (I) As for the (not yet available) web services (potentially provided by MR, FWD, LSP, and FC) supplying other business partners with real-time data as well as making it possible to place, modify, or cancel orders, a business model analysis seems promising. (II) Since this research has limited representativeness, further identification of SCEM-related services (referring to other industries, e. g.) is required. (III) A survey of commercial SCEM solutions (especially concerning their functional coverage and service-orientation) is appropriate. (IV) Last but not least, an illustration of an actual realization seems useful in order to demonstrate both feasibility and potentials of service-oriented SCEM

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The Nature of Knowledge-intensive Person-oriented Services – Challenges for Leveraging Service Engineering Potentials

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Abstract: Knowledge-intensive person-oriented services (KIPOS) are predominately existent in sectors such as health care, home care or education. They are of high economic relevance in terms of market size and growth. Yet they are laggards in terms of leveraging typical service engineering potentials as applying (partial) automation, process standardization or customer integration techniques, since the most value creating activities in service provision are bound to persons or personal knowledge. In this paper, we first analyze existing typologies from literature and derive a characteristic profile of KIPOS. Next to this, we present specific challenges for KIPOS engineering derived from qualitative interviews with service providers and observations. Our results can serve as an input for developing service engineering methods for KIPOS.

1 Introduction and Background

The service sector was long thought to be a laggard with regard to innovation, as it was assumed to be an uninteresting adopter of existing technologies rather than a producer of new technology. This perception still exists, and is a major reason why innovations in services remain under-researched [Ma06][ST06].

Services dominate western economies, accounting for about 70% of employment and gross value added. Moreover, services are the only part of western economies to have expanded in terms of employment in recent years, as manufacturing, mining and agriculture continue to contract [MS08]. Especially knowledge-intensive person-oriented services (KIPOS) bear great economic potential, although little statistical data is available for this kind of services (see e.g. [RWI08] for Germany). Just the market for private consumption of health care services, for example, will grow by 27 billion Euros until 2020 [Ka05]. This is partly due to the demographic shift which leads to increased health care spending as well as to a higher private demand for home services [Oe05].

The potentials of the IT-usage in business are well-known. Amongst others, IT allows standardization and support of processes, automation or integration [Da93]. The use of IT also bears vast potential for services. On the one hand IT enables new forms of cooperation and communication in service systems [RS06], on the other hand it enables automation, standardization and new concepts for customer integration [FF05]. Much of service innovation is therefore about the adoption and effective implementation of IT tools [Zy06].

Though the application of IT is different amongst service sectors [Sh06]. KIPOS are still lagging behind on intelligent use of IT. Typical KIPOS are for instance nutritional or health counseling. They are highly individualized, knowledge-demanding and generally delivered face-to-face. Enabling IT potentials for such services raises problems existing design methods do not address [PFC08]. This is partly due to the fact that KIPOS face certain specific specialties, e.g. regulatory issues or retentions upheld by service providers and consumers, which leads to the prevalent notion that KIPOS are not suitable for systematic service engineering. In the case of health counseling, e.g. such specialties include that customers are sick and reluctant, relinquish privacy or are at risk [BB07]. Yet, several new technologies have been developed and introduced, especially in the fields of ambient assisted living or telemedicine, which might lead to service innovations also in these sectors. Despite this fact, only little of these innovations have been put into practice [CMG08][Es09]. This is also caused by a lack of methods to systematically develop economically reasonable and user-friendly IT-enabled services and processes [PFC08].

The objective of this paper is therefore to set the field for service research specially dedicated to KIPOS. We provide a characteristic profile of such services and develop distinguishing characteristics and challenges as a basis for further research activities. These can be useful for development of systematic service engineering methods for KIPOS.

1.1 Service Definitions

Amongst others, the term service can be regarded from two perspectives: from a business view and a technical view [Bu08]. Services in a business sense are characterized by intangibility, immateriality, simultaneity of production and consumption (uno-actu-principle), as well as the integration of the consumer as external factor in the process of creation. Service from a technical perspective is a software realized artefact that offers some functionality. Similar findings can be found in [CS06][RS06][ZB03]. For the case of the business-oriented services, service engineering can make contributions by supporting service provision by intelligent usage of information and communication technology [BW09]. Hence, this paper focuses on services from a business view.

1.2 KIPOS

Knowledge-intensive services are defined as follows: during production or process the generation or the use of novel knowledge accounts for a large proportion of the service [Ha99]. These services can be predominantly found in the sectors communication, financials, research and consulting, health care, education, media and logistics. Other authors use the expression "information-intensive" with a quite similar definition: information actions amount for the largest proportion of value created by the service system [AM95]. Information-intensive services additionally involve essential personal or physical interactions. These include amongst others vocational education, consulting, emergency and surgical healthcare, sales and personal resources administration [Gl09].

KIPOS are predominantly existent in sectors such as health care, home care or education [BG06]. Usually they are characterized by a high degree of customer interaction and are bounded to persons or personal knowledge. Other works use the concept of service systems. Those systems combine and integrate different service design contexts [Ma06][Sp07b]. Based on those works, [Gl09] introduces seven contexts for service design ("person-to-person", "technology enhanced person-to-person", "self-service", "multi-channel", "services on multiple devices or platforms", "backstage intense or computational services" and "location-based and context-aware services") which he applies on information-intensive services. Following this approach, KIPOS, as considered in this paper, can be defined as follows:

> *A KIPO service is a complex knowledge-intensive service system, which incorporates one or more person-to-person-encounters as fundamental and integral part of the service.*

A KIPO service though can be enriched by all other service design contexts. Though these criteria provide a general understanding of KIPOS, the level of abstraction however is still rather high. [BA01] considers person-oriented services in general, too, but he underlines the collapse of service production and service consume during the interaction between two people having different needs.

2 Taking a closer Look at KIPOS

2.1 Related Work on Service Typologies

In the following section we present a more detailed classification of KIPOS, based on existing service typologies. This will serve as a starting point for deriving challenges KIPOS pose to service engineering methods.

Current research provides various forms of one-, two- and multi-dimensional typologies to characterize services. One of the well-known two-dimensional typologies is the approach of [ML83], who differentiates between the degree of service individualization and the intensity of customer contact, and the approach by [EKR93]. They also use the degree of service individualization, but they examine the degree of customer's interaction as a second dimension. Furthermore, a third approach is to be mentioned, which deals with a systematization based on the type of the performance object and the type of the production of services [LW02]. Finally, [Be90] considers the dimensions services made by provider's personal or objects and services for the provider's customers or objects.

Regarding the multi-dimensional typologies the approach by [CG07] is to be referenced, who differentiates between shelf-life, simultaneity, ties to a particular location, individuality and degree of detailing. Another multi-dimensional typology developed by [MM82] characterizes services by means of the duration of interaction, the type of decision-making and the amount of information. [BG96] use a deductive typology to classify services along five complexity dimensions: number of partial processes, heterogeneity of partial processes, individuality, multi-personality and duration of the provision process. None of the classifications is yet detailed enough for a typology of KIPOS. Also further criteria have to be taken into account, e.g. from process or outcome perspective.

2.2 Allocating KIPOS

In order to derive a more formal characterization of KIPOS, we followed an approach of inductive typology to describe services [BG96]. By assembling one-dimensional as well as two- and multi-dimensional typologies, we extended this approach.

We identified various criteria to characterize services. The assembled list of criteria was checked against duplicates and specified properly. They were also checked for authenticity, integrity and clearness. Due to the vast number of service typologies, some criteria overlapped in content, which has been reduced as far as possible. Criteria that were not applicable to KIPOS were omitted, like "range of use", "provider's legal position", "purchasing phase" or "economic function". This resulted in 30 criteria, as shown in Table 1.

Criteria			**indiff.**		
character of output	tangible		2,4	1,3	intangible
execution of service production	personal	1,2,3,4			automated
recipient of service	at people	1,2,3,4			at objects
character of production of service	output-oriented	1,2,4	3		process-oriented
usage of service	for consume	1,2,3,4			for investment
character of service process	material process		2,4	1,3	immaterial process
type of human input	intellectual	1,2,3,4			manual
degree of individualization	individual	1,2,3,4			standardized

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Criteria			**indiff.**		
degree of freedom in service production	creative	1,4	2,3		repetitive
uncertainties within the process of service production	problematic	1,2,3,4			unproblematic
duration of service	continuous			1,2,3,4	discrete
relationship between customer and provider	formal relationship		2	1,3,4	informal relationship
dominating factor for perceived service quality	person-oriented	1,2,3,4			equipment-oriented
product connection	isolated	1,2,3,4			combined
compulsion to contact	embodied	1,2,3,4			disembodied
place of production of service	tied to location		2	1,3,4	untied to location
temporal effect of provided benefits	permanent	3		1,2,4	non-permanent
elasticity of demand	price-elastic demand		3	1,2,4	price-inelastic demand
elasticity of salary	existential	2,4	1	3	luxury
used input factors	objects			1,2,3,4	personal
exclusion of demand	individual services	1,2,3,4			collective/community services
degree of customer's integration	high	1,2,3,4			low
output object	material objects		2,4	1,3	immaterial objects
character of customer integration	active	1,2,3,4			passive
relationship customer vs. provider	customer-dominant	1	3	2,4	provider-dominant
number of partial processes	high	2,4	3	1	low
heterogeneity of partial processes	high	1,2,4		1,3	low
duration of service provision	long	1,2,3,4			short
number of people involved in process	high	2		1,3,4	low
time aspect (customer's perspective)	time-saving			1,2,3,4	time-demanding

Table 1: Allocation of KIPOS to service characteristics: (1) life counseling, (2) home care, (3) on-the-job training / education, (4) medical consultation. (Criteria based on [BG06][BG96][CG07][EKR93][FF05][LW02][MB09][ML83][MM82][ZB03].

The resulting list of criteria served as a typology and was applied to four examples of typical KIPOS: (1) life counseling, (2) home care, (3) on-the-job training / education, (4) medical consultation. The allocation to the criteria was done separately by the authors and resulted in an agreement rate of more than 90%. The results are shown in Table 1.

Criteria showing a dominant pattern are candidates for representing a fundamental character of KIPOS, as they allowed an explicit allocation. Criteria offering an equal distribution of the examples can be important insofar as they reveal KIPOS that can be designed either way.

2.3 Similarities between KIPOS and other Services

Although some of the criteria are self-evident, others need to be explained in more detail. It is also not surprising that KIPOS reflect several characteristics that are commonly associated also with other services. The output of KIPOS is intangible and the recipients of the output are generally people not objects. This fact is obvious, as for example a medical consultation is always oriented to a person. Of course, if a physician conducts a surgery the output is tangible. Yet, the consultative aspect of a medical consultation can be regarded as dominant.

Like many other services, one characteristic of KIPOS is the integration of the customer that also leads to the compulsion to contact. Training on the job e.g. is obviously a service that requires the contact to the customer. Without physical or at least intellectual presence the service will not succeed. This example also explains that the customer's cooperation is necessary. As long as the attendees take part in the training in an active manner, the further training makes sense otherwise knowledge-transfer will not be initiated. Regarding customer integration, KIPOS can be characterized by four dimensions: the degree of integration is high, customer participation is active, it is time-demanding and the customer is embodied into the process. As a consequence, within these services the proportion of person-to-person encounters during service provision is not only immense, but also quite demanding on the customer. Hence, customer behavior, motivation and commitment can be regarded as a risk factor for service provision. As the customer has to be integrated within the process of service production, a large number of direct contacts between provider and customer are necessary. So, besides designing appropriate processes of service production, high quality customer interfaces need to be developed. These can also be realized by IT.

Due to the high degree of individualization, KIPOS have to be considered as problematic. As this criterion is not stated clear in current research literature, "problematic" can be defined as predictability of the process sequence. Especially in health or home care, incidents or unexpected diagnosis can result in a totally different service provisioning process thereafter.

Another revealed criterion is the isolated offering while the duration of the service is discrete. That means KIPOS are not combined with commodities respectively objects. This becomes evident in counseling, where the client is getting recommended actions. It is as well a discrete service, what means KIPOS are produced for a specific need at a certain time – in this case an advice for a specific client problem.

Furthermore, KIPOS are time-demanding from customer's perspective and the provision of service is time-intensive by itself. Performing a counseling is always time-demanding, e.g. because of holding meetings, in which targets and agreements are defined, problems are discussed etc. Simultaneously the process of service provision by itself is also time-consuming as a result of the complexity, the integration of the external factor, or the adaptation of the service.

3 Challenges KIPOS Pose to Service Engineers

Despite similar to other services in certain respects, KIPOS also have some characteristics that makes them special and uncommon. The following sections describe key challenges KIPOS pose to service engineering.

Additionally to analyzing and interpreting the dominant pattern from table 2, we conducted qualitative interviews and collected data as participant observers in various KIPOS settings. In detail, two interviews were made in the field of counseling, one of them with a nutritional counselor, the other with an agency that advises older people in different aspects on how to maintain independent living. Four interviews were conducted with home care service providers. All interviews were recorded and lasted between 30 and 45 minutes. On top, we visited an outpatient clinic and observed three patient-physician encounters, followed by short interviews with the physicians. We took detailed notes during these observations. For the field of education, we could rely on our own experience as university and provider of professional and on-the-job education that completed and influenced our research. The main goal of our interviews and observations was the identification of key characteristics of KIPOS in the fields of health care, counseling and education.

3.1 Every Customer has his/her own History

A fundamental key finding of our research is the high degree of individualization in KIPOS, caused by the huge amount of information necessary for adequate service provision. Every customer has his individual biography, medical background, lifestyle etc. As KIPOS need to be designed to fulfill the specific needs of each customer, this results in a big challenge for service providers. Every time they are facing a customer, they have to adapt themselves to the individual situation of the person in front. This is essential to build up trust and to get access. If the customer is not willing to interact with the service provider, no service production will be possible. Due to this, the practical and emotional knowledge (empathy) of the service provider is essential to get access to the customer and to understand his needs. One interviewee mentioned that they document the biography of patients who are suffering from dementia. The documentation helps the care worker to get a better understanding of the life situation of the patient and thus improves the interaction with him. The interaction is prevailing responsible for the perceived quality of the service by the patient. Due to this, the qualification of the care worker and the ability to understand the patient needs is very important for the service provision.

This poses also an enormous challenge to KIPOS development, as establishing an adequate information basis is very time-consuming and additionally relies on information directly communicated by the customer. Recent works try to overcome this deficit by establishing electronic data capture by customers or patients themselves [PML09], yet this is not possible for all kinds of information. With regard to KIPOS, we conclude that an individual information basis is a fundamental key characteristic, which has to be considered by the development of such services.

> "The key challenge for the care worker during the service provision is to win the patient. From the perspective of the patient, it is his private sphere that is entered. The distance not to cross the border is very tight, especially in Home Care. (interview with a home care provider)"

3.2 Emotional Tie and Stress

Another direct consequence from this is that delivering KIPOS can be emotionally daunting. Especially in home care or life counseling, the service provider need to fully understand a person's history, life-style and emotional being in order to be able to provide the service accordingly. This can be stressful as e.g. customers are sometimes incurable sick, have encountered strokes of fate, or are solely somewhat of a difficult character to deal with. Yet building up an emotional relationship is often inevitable for solid service provision.

For service engineering, this encompasses certain challenges with regards to resource or personnel allocation. On one hand, service providers need to be kind of emotionally stable, on the other hand, once an emotional tie is established between a worker and a customer, the customer cannot easily be served by another worker.

3.3 High Degree of Implicit Knowledge

KIPOS rely on a high degree of implicit knowledge that is accumulated and used during service provision. In home care e.g. the working staff needs to evaluate and react on the patients' needs and health status. All of the interviewees underlined the importance of practical and emotional knowledge besides qualification. Our interviews revealed that there are different forms of implicit knowledge. It encompasses personal experiences with a certain customer, including emotional insights, a customer's individual history or impressions obtained during interactions. Other forms are experiences on how to read persons, how to interact with persons and to talk with persons, or how to interpret certain statements or actions. In none of the cases we observed there is any form of documentation on this knowledge, yet it is essential for efficient and effective service provision, and also has an influence on perceived service quality.

Another challenge is that documentation of implicit knowledge faces some limitations. On the one hand, it is very time-consuming and therefore often economically unreasonable. On the other hand, implicit knowledge is sometimes of emotional type or a sort of personal experience, which is difficult to document and thus not easy to transfer from one person to another. This complicates standardization and automation of such services. A further consequence of insufficient documentation is that it is hard to implement quality management and assurance measures.

3.4 Service Delivery is People-bounded

KIPOS are performed at people and the dominant factor for perceived service quality is the person providing the service. Thus, it can be concluded that KIPOS contain at least some partial processes that must remain as they are: person-to-person encounters that can hardly be standardized or automated. Therefore, a service engineering method needs to be able to identify these irreplaceable "moments of truth". It has to be able to cope with two different settings: such that must remain manual and such that can be standardized and automated. Thus, it needs to develop criteria on how to distinguish between those two.

Although automation is difficult, IT can be used to either assist the person in charge of service provision, or to enhance the interactions between customer and provider [FF05]. A service engineering method has to consider to which extent technology should be used and for which process steps. Yet, the use of IT generates even more challenges. As [GT09] point out, different interaction channels have an impact on customer perception and hence service quality. Service engineering methods have to cope with the fact that services are complemented or replaced by automated services. Other questions include to which extent customers can actually be integrated into the service provisioning processes, and where is an optimal trade-off between customer integration and perceived service quality.

4 Summary and Outlook

KIPOS, as defined in this paper, have not drawn quite attention in recent service engineering research. This is mostly due to the wide-spread opinion, that such services possess a characteristic nature that makes it rather impossible to apply systematic engineering tools to their development and to raise IT-potentials. Yet, the rise of new communication and information technology also bears great potential for sectors dominated by KIPOS. The research reported in this paper has set the basis for further research on service engineering for such services. We discuss several definitions of KIPOS and provide a decent characterization. Further, we identify distinguishing features and challenges KIPOS pose for a systematic service development and engineering.

A closer analysis also confirms, that in KIPO service settings, there are processes that should be continued to be delivered personally, as they are the most value creating activities [Es09]. Yet, IT can make a contribution by supporting these processes with IT systems, e.g. by providing information or templates that make the provision more efficient. Additionally, services typically contain sub-processes or activities that are more or less standardized for several clients or do not contribute a lot to creating value. These could be automated and delivered by IT systems to enable scalability. So far, most of recent literature deals with development of IT Services, E-Services, or hybrid products [Be08][BK05][FH07][KLK07]. First efforts to realize IT-potentials for KIPOS have already been successfully made [LDK02][LKK06]. Hence, further research has to assess and evaluate existing service engineering and design methods on their applicability for KIPOS. It has also to be elaborated, what classifies a method and to what extent these methods can be automated.

We are aware that certain aspects of KIPOS are such specific that there will be hardly a possibility to apply standardization, automation or customer integration techniques. Nevertheless, there is a potential for at least partial, intelligent service engineering for KIPOS which needs to be developed to increase efficiency and effectivity of KIPOS or even pave the road for entirely new, IT-enabled KIPOS with new business and service models thus fostering growth and prosperity.

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Service Catalogue and Service Sourcing

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Abstract: Service management organizations and processes increasingly become standardized and even certified according to ISO/IEC 20000-1, creating detailed knowledge of the IT services rendered. The description of the services in a service catalogue needs to be enhanced beyond the components of IT services to include all contributing organizational units and business processes. An integrated model of the service catalogue is developed, visualized in a novel way and exemplarily applied to a large service provider. Finally, its usage for balanced sourcing decisions is discussed.

1 Service Management as Part of the Service

The provisioning of complex and cost efficient services almost always involves one or several integrated IT solutions – which in turn render IT services for internal or external customers. In the example of Toll Collect GmbH, the business services for the German electronic toll for heavy trucks involve more than 50 IT services ranging from standard IT applications (e.g. central billing processes, customer relationship management, and document management) to highly service-specific customer processes. The service levels are established according to the customers' requirements and typically involve availability, performance and failure rate as metrics. As a result the most critical services are operated 24 by 7 in a fault tolerant environment consisting of several hundred servers regularly communicating with more than 650.000 units in the field.

Since late 2005 it is possible to certify the management of IT services, i.e. the organization and its processes according to the international standard ISO/IEC 20000 [ISO05]. The certification of a service management organization ensures the implementation of processes covering all requirements defined in the ISO/IEC 20000 norm – including different perspectives of customers, services, technology, finances and suppliers. As a result a certified service management organization has a working definition and knowledge of services and corresponding technical configurations – the service catalogue and the configuration management database (CMDB).

However, the separation of services and the organization needed for rendering the services is an artificial simplification. It must be assumed that any large-scale service includes the behaviour of the organizations and people involved in the usage, operations and development of the service systems (therefore corresponding to an E-type system [Leh80]). Non-technical aspects of the service e.g. customer satisfaction, usability, time-to-market for new features and operational quality are added to the service level agreements on an equal footing. The behaviour of the service management processes and organizations becomes itself part of the service, even if it is not specified in the service level agreement [Leh05].

2 Service Architecture

The service provider organization needs a clear description of the service to be rendered for a customer including specific quality criteria regarding the service provisioning processes. This is typically formalized in a contractual document called service level agreement (SLA) [OG07a]. The SLA document represents the interface between customer and service provider and thus captures the customers' expectations as well as the service providers' degree of freedom, which enables both parties to create a cost-effective service supply chain. This in turn leverages the core competencies of the participating service provider and service customer organisations ([Fit08], [Lov10]).

The SLA captures the customers' perspective of the major service features and criteria. Depending on the kind of service, different descriptions and levels of detail are appropriate:

- The most complex – and also highest-value type of service is to offer complete business processes to the customer e.g. financial transactions or software development and testing. In this case the SLA focuses on process-specific parameters, the service provider is free to choose the internal service operations independently, e.g. the technology stack, the service management processes and organizations. The same business process can be offered as a service to other customers, allowing an increase in process efficiency by a factor of ten [Ham01].

- In many cases the responsibility for business processes remains with the customer to a much higher degree, yet some or all supporting IT applications as well as partial business or support processes reside with the service provider. The responsibility for aligning business processes to IT services (giving rise to the discipline "IT business alignment") remains with the customer. In this case the SLA is not able to capture end to end customer business process specific requirements – it has to "fall back" to technical parameters of the IT applications e.g. availability, recovery time or transaction rate. The service provider still has the choice of appropriate technologies, processes and organizations involved in the service provision. Consequently the technical description should not be part of the SLA but rather make up the internal service description – the service catalogue. Gradually even more simple services appear and can be used as service components within more complex service, e.g. technology driven commodity-like services (storage, data networks, and virtual servers).

Of course both models can co-exist within a service sourcing relationship e.g. providing the software development and testing processes as well as the application operations.

2.1 Configuration Management Database

Regardless of the kind of service provided the service provider needs an accurate description of all contributing parts necessary for the successful service operation. The ISO/IEC 20000 ITIL-based framework establishes a configuration management database (CMDB) as the repository to store configuration items and their respective logical and physical relationships. Even with these established best practices, only 41% of German companies with more than 1000 employees currently have a working CMDB [ITS10] – the complexity of the IT is the major driver for introducing a CMDB.

The CMDB as a data repository stores configuration items vital for most of the service management processes – most notably the change and incident management processes [OG07b]. Therefore it addresses the technology operated for the services provided (Fig. 1) – giving a detailed technical mapping of the physical infrastructure (e.g. data networks, hardware and data centre infrastructure) as well as logical elements (e.g. virtual resources, storage units, databases and applications). A rather abstract part of the CMDB can also store a description of the information architecture i.e. the data items and data models used across applications – e.g. facilitating security analysis based on data protection requirements.

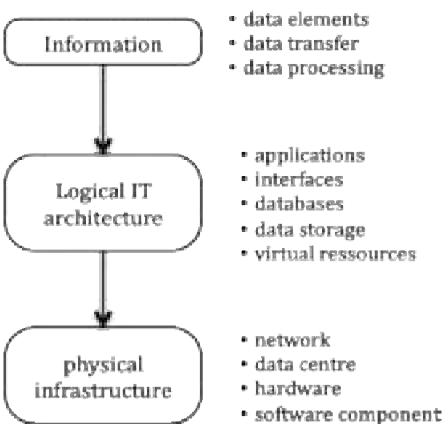

Figure 1: The CMDB model

2.2 Service Catalogue

The SLAs describe the customers' perspective as the starting point for the service provider to enhance the service descriptions for the design, implementation and operation of the appropriate technical systems using the providers' service management processes and organizations – usually including suppliers for parts of the service. The service catalogue is the major enabler within the service providers' organization and therefore needs to enhance the SLAs by service specific solution descriptions e.g. the functional requirements and architecture of the IT services (see fig. 2). Based on the solution descriptions the service provider decomposes the service into its service components. Each service component is in itself a service that is completely rendered by a single responsible organization. The service catalogue is therefore essentially the service configuration management database storing all service components and their respective relationships. The service catalogue transcends the CMDB by including all types of services: business process services (e.g. service levels for traditional service management processes), application services and typically a large number of technical infrastructure services.

In the example of the central billing processing application at Toll Collect GmbH more than 200 service components are needed to provide the service to internal and external customers. Each type of service component is thereby accompanied by a standardized description including

- a functional description
- the service levels (parameters)
- interfaces with other compatible service components
- organizational, contractual and financial details.

The service components as simple "service building blocks" within the service catalogue connect the SLAs to the component specification, i. e. either to the technical elements within the CMDB or further underpinning contracts and operational level agreements.

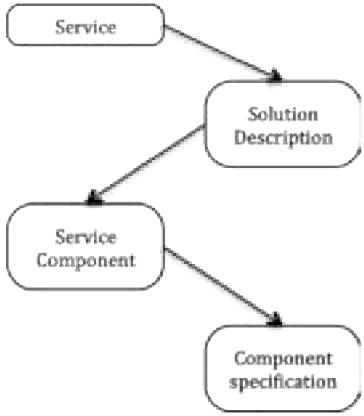

Figure 2: The service catalogue

3 Service Cost Mapping

Based on the service components and their relationships within the service catalogue and their relationships with the contributing configuration items in the CMDB, the service catalogue can give a complete picture of the service landscape.

Enhancing all elements of the service catalogue and the CMDB to also carry financial information allows the accurate calculation of the costs associated with a service (or a service component). However, the data set involved may not allow a simple interpretation since even small services can involve several hundred of cost contributions. An intuitive visualisation of this data can be an aid for the interpretation and as such of the management of the service. Such a visualisation of the cost contributions may help to identify relevant and major types of cost as well as the cost trends. We propose to use sunburst diagrams [Sta00] to give a compact view of services involving hundreds to thousands of cost contributions.

In the Toll Collect example sunburst diagrams are used to navigate service costs (fig. 3). Major cost contributions can immediately be spotted and form the input for further sourcing discussions. Fig. 3 shows the hierarchical representation of all cost contributions to the operations of a large-scale financial service. The innermost circle represents the sum of all costs as indicated by the adjacent slices. In a sense a service component is drawn as a slice with its opening angle proportional to the associated costs (with 360° opening angle corresponding to 100% of the cost). These associated costs can either be caused directly by the service component or collected from other related down-stream service components. The shading indicates different cost types.

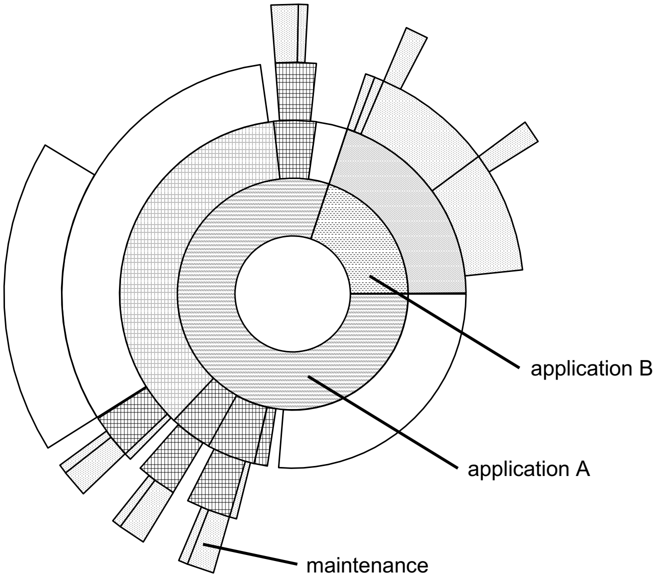

Figure 3: Sunburst visualisation of service costs

In the example the various contributions of maintenance cost are indicated and readily allow putting this cost type into proportion. This kind of visualisation has enabled the analysis and a considerable reduction of costs for service components by aiding to focus on relevant yet changeable and variable cost types.

4 Service Component Sourcing

Based on the service catalogue and the service costs it is possible to systematically derive the right sourcing decisions aligned to the customer services and the service providers' service management processes and organizations.

The first step is to identify the financially relevant service components (or types thereof) – ranging from business processes to technical commodities.

In the Toll Collect example we supplement the service cost maps by treemaps [Shn92] displaying the costs associated with certain types of service components (see fig. 4), e.g. distinguishing between highly standardized service components (networks, servers, databases, applications), non-standardized service components (custom applications and equipment), business processes (e.g. software development and testing processes) and temporary services required by projects.

In treemaps the whole drawing area carries information whereas in the sunburst diagrams the information is primarily displayed along the circumference making limited use of the available area. As a consequence of the higher information density, treemaps can include more details yet remain comprehensible at a glance.

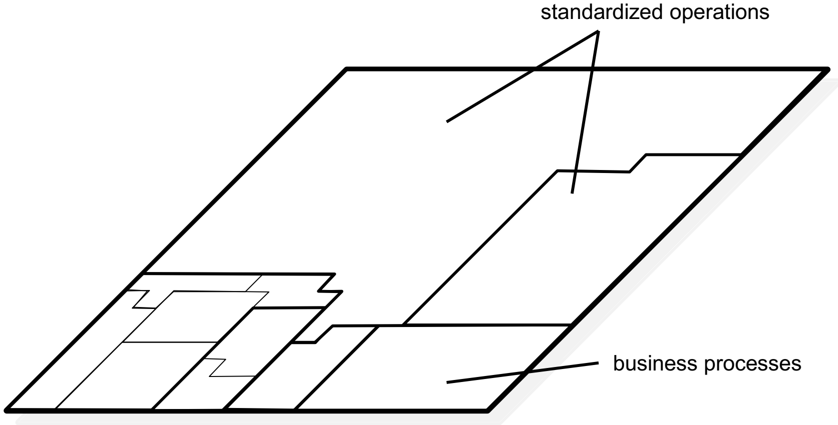

Figure 4: Treemap visualisation of service costs across the service catalogue

Once the relevant service components have been identified, the appropriate sourcing can be discussed using the customisation-specificity map [PJG09] which applies seamlessly to technical, organisational and process-driven service components.

5 Conclusion

The delivery of services – even largely IT-based services – goes beyond the standardized ISO/IEC 20000 service management to include business processes and organizational features. The service provider can and must decide upon many aspects of the service independently from the customer yet fulfil the service level agreement.

An integrated, accurate and complete overview over all services and their internal working details enables the service provider to identify and address the sourcing in a coordinated way using the established customisation-specificity maps. The service catalogue as the principal mapping between SLAs, technical configurations, organizational and process-driven service components has been shown to enable the sourcing decisions based on sound financial reasons. This can be facilitated by appropriate visualization techniques such as sunburst and treemap diagrams.

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Fostering the Virtualization of Service Processes and Touch Points – Identification and Documentation of E-Service Potential in Retail Networks

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Abstract: Offering business services is widely considered a means for superior value creation. Increasing research activities in the emerging disciplines of Service Sciences and Service Science Management and Engineering (SSME) can be ascertained. Even so, the integration of service processes and their virtualization with suitable IT artifacts is seldom focused in SSME. Building on the Process Virtualization Theory (PVT), we propose ways to assess and document the eligibility of service processes and—on a more detailed level—of the activities that need to be virtualized among the stakeholders. On a process level, central questions are derived from the PVT. On an activity level, an extended service blueprinting notation is derived and conceptualized in a language-oriented meta model. We demonstrate the usability of our approach with an exemplary service process from the retail sector. Since the retail sector is quite mature, the concepts to be used there might also be reused in other service settings.

1 Introduction

More than ever, business is no longer about simply selling physical goods to customers. Instead, solving customers' problems (solution business) provides companies with a competitive edge. Some researchers even propose a paradigm shift in thinking about the creation of value from a "goods-dominant logic" to a "service-dominant logic" point of view [VL04]. In this context, all value creation is achieved by combining physical products and services into customer solutions that satisfy a customer's needs [Ch07].

Generally, efficient service processes have to be designed to be integrated in two respects: On the one hand, recognizing customers as a "co-creator of value" [ZB96] demands an integration of service processes with a customer's business processes. On the other hand, service providers have to ensure an efficient integration of service processes with their own (physical goods and services) backstage processes (e.g., manufacturing processes) in order to reach the operational excellence to satisfy their clients' needs efficiently [RK03]. To aid the integration of business processes in both directions, it is feasible to use electronic service concepts (E-Services) for the virtualization of services that might have been conducted physically or even manually in the past. Virtualization helps improve efficiency in terms of process cycle times, quality, or availability.

The phenomenon of "process virtualization" is relevant in many contexts, including distance learning, friendship development (e.g., via social networks), or electronic shopping through electronic commerce [Ov08]. With regard to process virtualization, E-Services are services that are made available via electronic networks, e.g., on the Internet [SW08]. In general, services usually tend to be oriented downstream [WB99] from the value chain (e.g., provided to customers) or upwards from the value chain (e.g., provided to producers) [SW08]. Hence, E-Service providers need to integrate information that is provided by customers as well as information that is provided by producers as co-creators of value in service systems [Ma09] in order to optimize their own processes.

In economic theory, the retail sector's role is to overcome negative side effects in consequence of the division of labor. The retail sector balances differences between supply and demand in terms of space, time, quality, and quantity of goods. Hence, the retail sector provides services for industrial companies (i.e., manufacturers) as well as for consumers at various parts of the supply and demand aggregation (cf. table 1).

Pre Sales Services	**Services During Sales**	**After Sales Services**
• Master Data Management (Creation and Verification, e.g. individual Description for Electronic Devices)	• Product Advice	• Product Delivery (e.g. Furniture Retail) and Initial Operation
• Creation of Product Pictures	• Product Configuration (e.g. Car Configuration)	• Hotline
• Timely Disposition of Orders in Order to Avoid Out of Stock	• Contracting (e.g. Car Contract)	• Maintenance
• Product Distribution (e.g. from Central Warehouse to Stores)	• Credit Approvals	• Guarantee Management
• Shelf Management	• Leasing	• Reclamations
• Product Tests in Test Stores	• Granting of Loans	• Redemption (Batteries, Used Devices, ...)
• Product Listing and Price Calculation	• Disposal of Expired Goods	• Waste Disposal (Used Devices, Batteries, Packaging, …)
• Promotions	• Cash Withdrawal via EC or Credit Cards	• Customer and Product Basket Analyses, Sales Analyses
• In-Store Promotions	• Customer Data Collection	• Encashment
• Offline Promotions (e.g. Newspaper Advertisements)	• Product Basket Collections	
• Online Promotions (e.g. Banner Ads)	• Coupon Redemption	
• Product Placement and Space Management	• Coupon Issuing	
• Customer Loyalty Programs		

Table 1: Exemplary of Retail Services for Industry and Customers

With such diverse individual services in retail, process virtualization—especially with the ease of information flow through the Internet—seems to be a promising reorganization strategy for superior service processes. A sound reorganization seems especially promising for the retail sector as many of their service processes are carried out frequently and, therefore, have to be very efficient and sophisticated. In addition, other service branches might increase their own efficiency by learning from service process optimization in the retail sector. However some service processes are more amenable to virtualization than others are.

Having this in mind, our article provides insights into how the virtualization potential of service processes might be identified and formally documented. To reach this objective, we present artifacts to support the analysis on (a) a service process level of detail and on

(b) an activity level of detail. We start by deriving central questions to assess coarsely the general potential of virtualization for a service process. For that, we apply the Process Virtualization Theory (PVT) [Ov08] to the domain of service processes and E-Services (Section 2). In addition to applying the PVT to service processes as a whole, we build on an extended version of the service blueprinting approach [BKM08] in order to visualize and document the virtualization potential on an activity level of detail (Section 3). Consecutively, we demonstrate the documentation, planning, and composition of E-Services with the example of a coupon service process as is frequently carried out in retail (Section 4). Finally, we present exemplary artifacts for integrating business processes in retail networks that can be used to exploit the identified virtualization potential (Section 5) and conclude the paper (Section 6).

2 Identifying the Virtualization Potential of Service Processes

A process is broadly defined as a set of activities for achieving a goal. A physical process is a process with physical interaction between people or objects and people. Hence, a virtual process is a process in which physical interactions have been removed [FO05, Ov08]. Often, virtual processes are enabled by IT and supported through the help of the Internet, but this is not necessarily the case all the time. For example, catalogue sales allow the non-IT-enabled virtualization of sales services processes through catalogue sales, whereas online shopping is an IT-enabled form of process virtualization.

PVT was first introduced by Eric Overby [Ov05, Ov08]. The purpose of PVT is to provide a general theoretical basis for investigating the factors that affect the virtualizability of a process. It is derived because many processes that have historically required physical interaction amongst participants are now conducted online or through other virtual means. Despite much research on virtual processes e.g., [PI78]; [DL86]; [MYB87]; [Da89], little attention has been paid to the question of what makes processes amenable or resistant to virtualization. For that, the PVT offers four main constructs (namely, sensory requirements, relationship requirements, synchronism requirements, and identification and control requirements) that allow for an explanation of whether a process is suitable for virtualization. In the following, we derive a set of central questions from the constructs proposed in the PVT to assess coarsely the virtualization potential of service processes.

<u>Sensory requirements</u> can be defined as the need of process stakeholders to enjoy fully a sensory experience while conducting the process. Those experiences can be in the way of hearing, seeing, smelling, tasting, touching, or generally engaging in the process. From the point of E-Services, we are able to derive two main questions as follows: **SR1**: Will participants accept a virtualized service without being able to enjoy sensory experiences fully?

SR2: If not, is it possible to overcome the need with the help of, for example, process changes or improvements, technological adaptations or social fortifications?

For example, it is hardly possible to sell perfume over the Internet (hence, to virtualize perfume sales) due to a lack of smelling experience. However, technological devices that are able to imitate the smell within consumer homes may overcome the problem.

Relationship requirements define the need for process stakeholders to interact with each other in a social or professional context in order to acquire knowledge or develop trust or friendship. From the point of E-Services, this leads us to the two following questions:

RR1: Will participants accept a virtualized service without being able to satisfy their relationship needs fully?

RR2: If not, is it possible to satisfy the relationship needs virtually, e.g., through video clips in online shops, through video conferencing, or through utilizing social networks?

For example, video conferencing turns out to substitute more and more business travel as it is possible to not only hear but see and interact with each stakeholder of the business process. Video clips are increasingly used on E-Business web sites to provide a richer sense of how, for example, clothes would look, while social networks might convince customers that their decision to buy a product is a good one.

Synchronism requirement is the degree to which the process activities need to follow one another. Working asynchronously within one process may work for some processes, but delays may not work for every process.

SyR1: Will participants accept a virtualized service without being able to work in synchrony fully?

SyR2: If not, is it possible to reorganize the process or to use other technologies in order to synchronize process activities?

For example, unlike email, chatting or other real-time collaboration tools allow for synchronous discussions between process stakeholders. Hence, some retailers already use this communication technology in order to synchronize their virtual support discussions with their customers.

Identification and control requirements address the requirements of a unique identification of process participants and the ability to exert control over them and to influence their behavior.

ICR1: Will participants accept a virtualized service without being able to identify other process stakeholders?

ICR2: If not, is it possible to implement some identification mechanism that overcomes the obstacle?

ICR3: Will participants accept a virtualized service without being able to control or influence other process stakeholders?

ICR4: If not, is it possible to implement some influential or control mechanisms in order to overcome the obstacle?

For example, when eBay went online, the company soon implemented a rating mechanism for transactions in order to give eBay members some sort of control and virtual identity for their transactions.

Keeping in mind that processes can be virtualized either with or without the use of information technology, PVT explicitly addresses the theoretical significance of information technology in process virtualization by discussing the moderating effects of representation, reach, and monitoring capability. Those moderating effects allow the deduction of additional central questions for the assessment of the virtualization's applicability for individual retail services.

ME1: Is it possible to moderate sensory requirements with the help of a suitable representation of process information through IT, e.g., detailed product pictures instead of seeing and feeling a product in a physical store?

ME2: Is it possible to moderate relationship requirements with the help of a suitable representation of stakeholder information, e.g., social profiles as in social networks?

ME3: Does the reach of virtual processes through information technology enable activities beyond physical boundaries in time and space, e.g., 24/7 worldwide online shopping instead of limited opening hours of physical neighborhood stores?

ME4: Does the reach of virtual processes through information technology allow a better support of synchronism requirements, e.g., co-browsing through online stores?

ME5: Does the monitoring capability of information technology allow a better addressing of identification and control requirements of virtualized processes, e.g., monitoring previous transactions of potential buyers and sellers on e-commerce platforms such as eBay?

3 Identifying the Virtualization Potential of Touch Points

The previously derived central questions help to identify the suitability of physical service processes for virtualization on a coarse detail level. However, in most cases, it will not be possible to virtualize entire service processes with the help of IT. For example, although products might be presented and sold online, they still need to be delivered physically to each consumer. Consequently, instead of referring to the service process as the unit of analysis, in a second step, we will rather have to evaluate the virtualization of "touch points" among process stakeholders. Touch points imply that information is transferred between two or more stakeholders in the process chain. These information flows can be supported by virtualized processes [RK03].

For analyzing touch points in-depth, we can draw from the well-established service blueprinting approach as is traditionally proposed by the service marketing discipline

[Sh82]; [ZB96]; [Kb89]. Primarily, service blueprinting emphasizes the provider-customer interface of service processes. Being more of a diagrammatic illustration of a service process rather than a formal modeling language [BBK10], the service blueprinting approach traditionally distinguishes *activities* to be carried out by service providers and customers in the front stage and backstage of service systems confined by several "*lines*" (see figure 1 for illustration). Activities might be customer activities, onstage activities of a service provider, backstage activities of a service provider, and support processes. The "line of interaction" and the "line of visibility" are of special importance to clarify the roles of service providers and customers in service systems and to determine the detail level of the information to be shared amongst stakeholders.

- The "line of interaction" divides the activities of a process to be carried out by service providers from the activities to be carried out by customers. Therefore, adjusting this line towards the service provider implies a more extensive involvement of customers in the service process (e.g., by more self-service). Accordingly, adjusting the line towards customers adds more activities for service providers, reducing the involvement of the customer in the service process.

- The "line of visibility" determines the scope of information provided to customers related to a service provider's business processes. For example, in many countries, customers are able to track their parcels from their origin to their destination via the Internet. By adjusting the line of visibility towards service providers, customers are provided with more information, e.g., about the current location of the parcel. By reducing visibility of activities for customers, service providers may restrict their customers from gaining information about their service processes.

Both lines have to be adjusted purposefully in each service system to govern the service activities—e.g., in terms of outsourcing or in-sourcing—and to determine the degree of information to be shared in each service process. Originally proposed by [Sh82], the service blueprinting approach has been extended and revised by other authors [Kb89] [Kb95] [Kl00] [FK04] [BOM07].

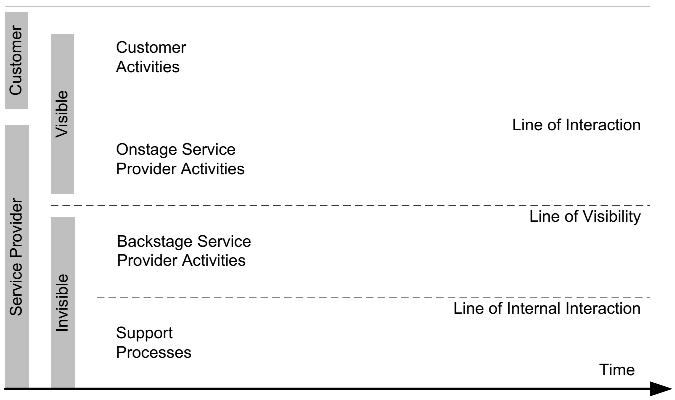

Figure 1: Service-Blueprinting approach as proposed by Bitner, Ostrom, and Morgan (2007)

All of the proposed services blueprinting approaches have been designed to emphasize the service provider's interface with their customers. Even so, to depict the service process (and its degree of automation) in its entirety, it seems beneficial to incorporate stakeholders from the upper end of the value chain into the service blueprint [BKM08]. Therefore, we propose extending the service blueprinting approach to comprise the interface of service providers towards their suppliers. With retail services, this would be the retailer-supplier interface. The idea is to introduce additional layers into the blueprint by partially mirroring elements (an approach that has been elaborated on elsewhere [BKM08]), i.e., the lines of interaction and visibility (cf. figure 2). By bridging the front stage and backstage of services [GT09], all activities of service processes can be streamlined ultimately to influence a customer's service experience positively. In our proposed approach, several of the previously proposed lines are not included. This is conceivable because from a retailer's point of view, they are not necessary to identify and automate touch points towards customers and suppliers because any of those activities are, in fact, encapsulated in the middle layer of the blueprint.

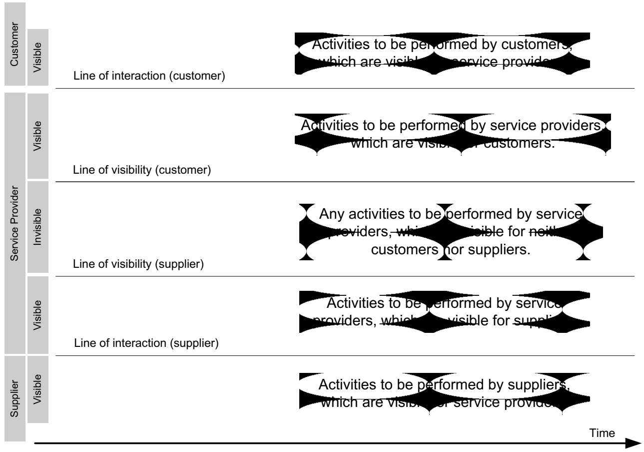

Figure 2: Concept of an extended mirrored service blueprint for depicting service processes

To specify the rules and possibilities of blueprinting, it is beneficial to formally explicate and revise service blueprinting with the help of its meta model and to introduce graphical representations for any of the (additional) language constructs. Previous versions of the blueprinting approach however failed to provide a meta model. Therefore, before we can adapt the service blueprinting approach into a mirrored blueprint to also document touch points and information flows in service systems, we have to reconstruct the meta model of the traditional blueprinting approach (figure 3). *Process Elements* to be found in the blueprint can be the *Activities* to be executed, *Decision Nodes*, *Physical Objects*, or *IT-Systems* (e.g., databases). *Activities* are assigned to different *Layers* confined by lines, whereas *Decision Nodes*, *Physical Objects*, and *IT Systems* transcend the lines and, therefore, are not assigned to layers. *Connectors* split or join the control flow of the service process. Any of the *Process Elements* can be connected with each other by *Edges*. For *Activities*, the allowed *Execution Time* (i.e., relation start and end dates) can be specified.

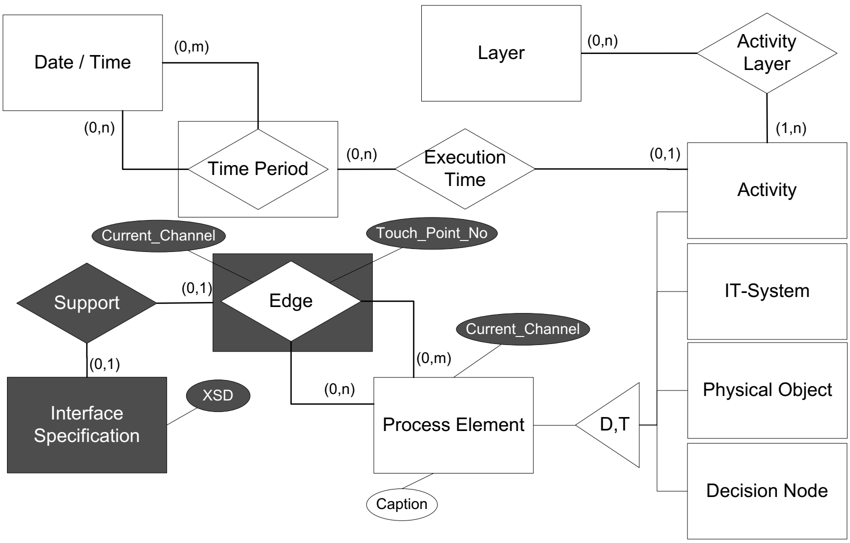

Figure 3: Reconstructed Meta-model of the Service Blueprinting Approach (white objects) as proposed by [BOM07] and the extensions proposed in this paper (grey objects)

To be able to use the mirrored service blueprint as a basis for the formal analysis and for the documentation of information flows at touch points, we propose the introduction of some new language constructs into the service blueprinting meta-model (grey shaded objects in figure 3). On the one hand, the attribute *Current_Channel* is added to any of the *Edges* in the blueprint to document by which channel (e.g., paper sheet, fax, phone, specified electronic document, or web-service) the information is currently transmitted. This extension seems to be valuable to document the potential for a further digitalization of information flows. Furthermore, it is beneficial to understand the nature of the current cooperation in the established service system better. On the other hand, for each of the *Edges*, a formal *Interface Specification* can be assigned to specify the structure of the information to be transmitted (e.g., in an XML document).

Once the potential of automating a service process has been assessed (into which the derived central question can easily be included to investigate all of the touch points with the PVT soundly), the extended service blueprint can be utilized to analyze the service process, acting as starting point to conceptualize, build, and evaluate appropriate IT artifacts for the entire service process. Also, all of the developed IT artifacts can be documented in the blueprint to display the new status of virtualization.

4 A Retail Network Example for the Identification and Documentation of Virtualization Potential for Service Processes and Touch Points

In the following, we exemplify the evaluation of service processes and touch points with the example of coupon promotion services in retail. In addition, the graphical representations corresponding to the proposed meta-model extensions are presented. A coupon promotion is a sales instrument conducted by retailers, but it is launched by an industrial physical-goods supplier in most cases. Consumers receive rebate slips that allow them to buy particular products at a discounted price. The processes to be performed by retailers (redeeming party) and manufacturers (issuing party) are cooperative because they must jointly define the promoted products, the face value of the coupon, the start and end dates of the promotion as well as the amount of coupons to be issued.

On a process level of detail, we use the central questions as derived in Section 2 to estimate the virtualization potential of the entire coupon service process. Importantly, our approach does not constitute an objective weighted aggregation approach, since the suitability of weights for the central questions is contingent on the properties encountered in each design context. Thus, rather than quantitatively computing an eligibility score for each touch point, the approach serves as an analytical lens for qualitatively assessing their eligibility for virtualization. Bearing this in mind, the results suggest that the couponing process generally is amenable to virtualization (Table 2). We use this evaluation as a general estimation of the virtualization potential before the in-depth and time-consuming analysis with the blueprinting approach takes place for each process with virtualization potential. This two-step approach is especially useful when many processes have to be analyzed for reorganization, hence, virtualization potential. Depending on the effort a company is willing to spend on this analysis, surveys and analyses of qualitative data might even be performed.

Central question from PVT	Assessment for the "coupon dissemination and redemption" service process
Sensory Requirements (SR) 1 Will participants accept a virtualized service without being able to fully enjoy sensory experiences?	Yes, consumers will be likely to accept a virtualized couponing process without being able to fully enjoy the sensory experience because coupons generally do not convey rich sensory experiences besides being printed on paper. No, suppliers Used to "feel" all redeemed coupons because of fraud fears.
SR2: If not, is it possible to overcome the need with the help of e.g. process changes or improvements, technological adaptations or social fortifications?	For customers, the way of coupon issuing and redemption does not depend on any form of sensory experience. For retailers and suppliers, process changes and technological innovations are necessary in order to ensure a reliable coupon redemption and clearing without fearing fraud. In former times, consumers redeemed coupons in retail stores. Manual condition checks by store employees made the industry fear fraud. However, if it is possible to change processes in order to enable automatic condition checks, suppliers will likely accept virtualized couponing processes.
Relationship Requirements (RR) 1: Will participants accept a virtualized service without being able to fully satisfying their relationship needs?	Yes, consumers will most likely accept coupons in a virtualized process as there are no relationships associated with receiving or redeeming a coupon in retail. No, suppliers will need to know which retailers accept their coupons (in order to ensure a correct clearing process and to monitor fraud attempts). Furthermore, they would prefer to know which customers or customer groups like to redeem their coupons.

RR2: If not, is it possible to satisfy the relationship needs virtually, e.g. through video clips in online shops, through video conferencing or through utilizing social networks?	For customers, the way of coupon issuing and redemption is not depending on any form of relationship requirements. For suppliers, a virtualization needs to ensure that it is still possible to identify the retailer who has accepted the coupon. This is always the case as the retailers need to be known in order to reimburse them. However, with manual processing it was not possible to identify individual customers or customer groups. Hence, a virtualization may even overcome this obstacle.
Synchronism Requirement (SyR) 1: Will participants accept a virtualized service without being able to fully work in synchrony?	Most likely yes. Customers are used to receive coupons by mail (asynchronous with the redemption process).Also suppliers issue and redeem coupons at various points of times.
SyR2: If not, is it possible to reorganize the process or to use other technologies in order to synchronize process activities?	n.A.
Identification and Control Requirement (ICR) 1: Will participants accept a virtualized service without being able to identify other process stakeholders?	From the consumers point of view, other stakeholders are (a) retail company and (b) supplier, both of which can be identified from the information on the coupon, hence the question is not applicable. From a suppliers and retailers point of view, both know about each other as the issuer and redeemer information is stored on the coupon but they do not know about redeeming customers (also this knowledge would be favorable). With virtualization (e.g. issuing coupons via email) they will both need to ensure that consumers do redeem coupons unjustified.
ICR2: If not, is it possible to implement some identification mechanism that overcomes the obstacle?	Technical mechanisms for automatic redemption management may help overcoming fraud problems at the POS.
ICR3: Will participants accept a virtualized service without being able to control or influence other process stakeholders?	No matter the degree of virtualization, customers generally cannot influence the coupon process, because it is governed by pre-defined rules made up by retailers and suppliers (coupon master data and article master data).
ICR4: If not, is it possible to implement some influential or control mechanisms in order to overcome the obstacle?	n.A.
Moderating Effect 1: Is it possible to moderate sensory requirements with the help of a suitable representation of process information through IT, e.g. detailed product pictures instead of seeing and feeling a product in a physical store?	As customers do not have any sensory requirements there is no need to support it with the help of IT etc. In order to virtualize the issuing and redemption process and to being accepted by suppliers, IT needs to ensure that fraud is not possible when conducting the process virtually.
ME2: Is it possible to moderate relationship requirements with the help of a suitable representation of stakeholder information, e.g. social profiles as in social networks?	For customers, social networks can be setup to be used by customers to discuss on stakeholders and coupons. However, it is not necessary to address relationship issues for consumers. For suppliers, virtual processes have to ensure that coupon accepting retailers are known. For them, virtualized couponing processes would be beneficial if it will be possible to identify each redeeming consumer or consumer group.
ME3: Does the reach of virtual processes through information technology enable activities beyond physical boundaries in time and space, e.g. 24/7 worldwide online shopping instead of limited opening hours of physical neighborhood stores?	For customers, a 24/7 availability can be reached when utilizing the internet for coupon dissemination and redemption. For suppliers, gaining more precise information about customers through coupon redemption may help in better marketing and developing products.
ME4: Does the reach of virtual processes through information technology allow a better support of synchronism requirements, e.g. co-browsing through online stores?	This is most likely not necessary for coupon processes (low level of complexity, familiarity of the customer with the process). However, virtualized processes may allow a faster clearing of coupon promotions between retailers and suppliers.
ME5: Does the monitoring capability of information technology allow a better addressing of identification and control requirements of virtualized processes?	Customers can easily check if their coupon has been redeemed successfully (but no better than they could in a "brick-and-mortar" case).

Table 2: Assessing the eligibility for a virtualization of coupon processes with the central questions derived from the PVT

To assess the virtualization potential in more depth (i.e., by analyzing the potential for virtualization of each touch point), we applied the mirrored blueprinting approach. First, we transcribed the coupon clearing process [Wi06] to the mirrored service blueprint notation (cf. figure 4). In order to issue, accept, and redeem coupons automatically, article master data and promotional master data (e.g., validity period, region of acceptance, or face value) must be entered into the point of sale systems (POS) first. As a result, it becomes possible to electronically verify and accept a coupon by scanning its barcode at the POS. If the customer identifies herself (e.g., through a loyalty program card), it becomes possible to add her interest in the coupon promotion campaign to her customer record.

Coupons can be issued either in-store or remotely (e.g., on an E-Commerce website) because customers need not necessarily be present in order to buy products and to redeem coupons. Hence, it is possible to use various channels for the interaction between retailers and customers, which can be supported with E-Services. Interaction with suppliers can be conducted with or without involving human actors (interaction patterns 1, 2, or 3), depending on the current level of maturity retailers' and producers' IS support. All of the touch points were documented in the blueprint by numbered circles.

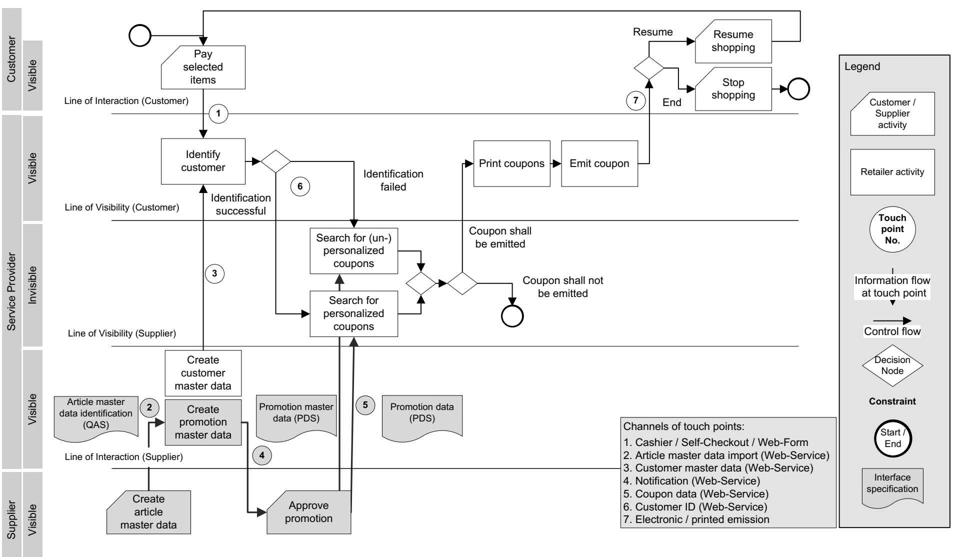

Figure 4: Mirrored Service-Blueprint for coupon dissemination and redemption service processes

5 Artifacts for Virtualized Service Processes in Retail

After identifying and documenting the touch points to be supported by, for example, inter-organizational information flows, IT artifacts can be designed to support the identified information flows in order to exploit their virtualization potential. IT artifacts can be categorized in different ways. Our lens is to classify them according to their granularity into task services and process services [BKM08]. Task services (e.g., a web service providing the required information) are used to virtualize one touch point only, whereas process services represent collections of task services that are ties together with additional application logic to virtualize a number of touch points simultaneously.

Web-Service-based Virtualization of Touch Points

Apart from the notion of "business" services, web services can be seen as one means of transferring the service paradigm to software components [Ve08]. Web services are one form of realization to provide a business service in value networks [Bu08]. As constitutional parts of service-oriented architectures (SOA), they are heavily debated with an emphasis on integrating information in E-Business scenarios [TK01]. Visions of creating SOA can be quite different, reaching from a dynamic, semantic search of web services described in UDDI repositories to rather conventional Enterprise Application Integration approaches like middleware platforms [Sc06]; [Al04]. Taking our mirrored service blueprinting approach as an analytical lens, the identification and design of web services in service systems can be completed by analyzing business processes at an activity level of detail. Approaches to achieve this have been elaborated on proposed elsewhere [BKM08] and, therefore, are not in the scope of this paper.

Whatever approach for specifying web services is used, the web services conceptualized can be represented on an abstract level in the mirrored blueprint with the extensions proposed in this paper (cf. figure 4), i.e., the element *Interface Specification*. In this way, an overview of the currently used IT artifacts and the degree of virtualization of the entire service process (e.g., a coupon service) can be conveyed.

Web-Service-based Virtualization of Service Processes

To achieve an efficient and, hence, virtualized dissemination and redemption process in couponing, article master data and coupon master data provided by manufacturers and retailers must be thoughtfully organized and provided [Wi08]. One way to achieve this is to design an integrated promotion platform on the Internet, which can be used as a central data repository for manufacturing companies and retailers to aid the coupon promotion processes. Coupon promotion processes aided by a promotion platform might be perceived by customers (e.g., reduced waiting times at the POS and more reliable redemption due to electronic promotions) and suppliers (e.g., fewer resources to set up and operate promotion campaigns, less coupon fraud, etc.) as a superior service experience. Therefore, retailers might want to analyze and design their service processes thoughtfully with respect to their stakeholders.

We designed and prototypically implemented a coupon promotion platform with the paradigm of a middleware approach [Sc06] to facilitate the inter-organizational cooperation of manufacturers and retailers with virtualized touch points (cf. architecture and grey circles in figure 5). The services provided on the promotion platform are managed by a Service Framework (SF), which provides for the integration of these services to support processes. The handling of article master data is crucial for designing and executing promotion campaigns in retail with automatic coupon clearing. Therefore, the platform has to provide adequate functionality to obtain, manage, save, archive, and provide article master data in the Item Data Service (IDS) Layer.

Besides article master data, the promotion master data of the promotion campaign (e.g., period, involved stores, clearing conditions, etc.) have to be administered on the promotion platform as well. The platform provides this functionality within the Promotion Data Service (PDS) layer. Functionality includes selecting article master data for promotions (*what* articles to promote), validity period of the promotion (*when* to promote articles), selected retailers (*where* to promote articles), and clearing conditions (*under which circumstances* to accept a coupon at the point of sale).

To provide article master data in sufficient quality, the Quality Assurance Service (QAS) layer implements functionality to keep the data repository up-to-date by identifying new article master data in data pools (such as SINFOS) and importing it. Similarity algorithms help to match new master data records with existing ones. The Platform Services (PS) layer provides functionality to administrate the platform.

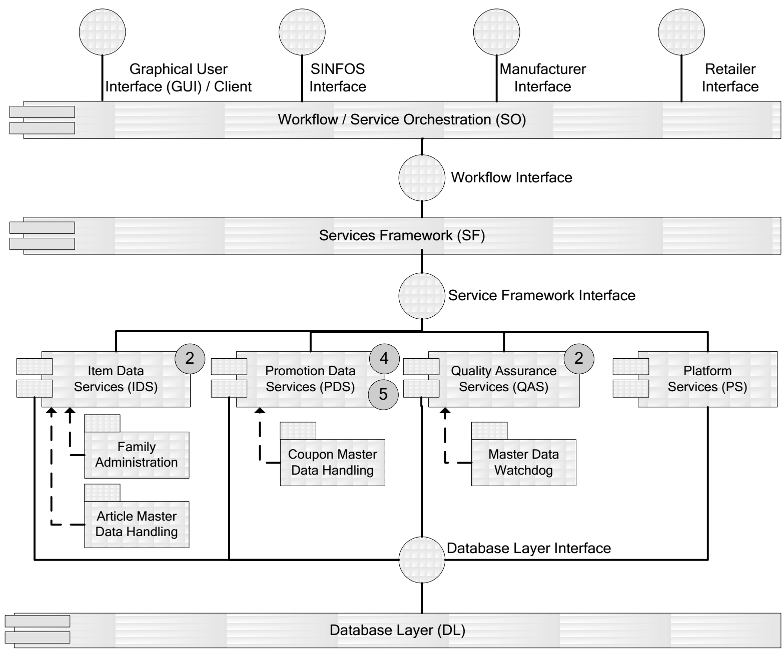

Figure 5: UML Component Diagram of the integrated coupon promotion platform

6 Conclusion

We proposed a method to assess the virtualization potential of service processes on (a) a process and on (b) an activity level of detail. On a process level, we proposed central questions that we derived from the Process Virtualization Theory in order to identify processes that offer virtualization potential. Subsequently, we built on the idea of a mirrored service blueprint [BKM08] to conceptualize an approach for identifying virtualization potential and formally documenting it with a language-oriented meta model. This formalized blueprint notation serves to initially depict the service process in its entirety and to document its current state of IT support at all times. Methods for designing IT artifacts for putting virtualization into action can be utilized consistent with this approach, but were not in the scope of this paper.

With our evaluation scenario from the retail sector, we provided evidence that the approach is usable to identify virtualization potential and document it formally to advance suitable artifacts further. The approach can be enhanced by subjecting our initial central questions to extensive qualitative and quantitative field-testing. With this approach, a set of generally accepted central questions might be established. Since the retail sector—however important— is only one domain pertinent to service science, we expect that adaptations of our approach would be also usable to virtualize other service processes, such as in Banking, e-Government, or Health Care. Applying the proposed approach might also highlight differences and commonalities for virtualizing touch points in different domains of application. For instance, touch points in health care or e-Government might not be amenable for virtualization due to legal regulations. Also, additional field test and consecutive design cycles are expected to increase the theoretical strength and applicability of the proposed approach.

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Can Tweets, Pokes and Wikis improve Global Software Services?

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Abstract: Social media sites are driving the development of the Internet. A detailed analysis of social media sites on a category level, revealed four key mechanisms. These are social context, content relevance, ease-of-use, and centralization of functions. The management of Global Software Services is increasingly supported by tools along the service life-cycle. It is argued these tools could be improved by systematically addressing the four key mechanisms. The implementation of these key areas is described and discussed in detail. The advantages and disadvantages are elaborated. The result of this contribution is that tools for GSS could significantly benefit from embedding socio-semantic elements.

1 Introduction

Most major companies develop software products in a globally distributed fashion. Some of the reasons for motivating Global Software Service (GSS) essentially force companies into GSS, while others promise economic benefits. As a result, it is not surprising that some projects fail, even though a lot of attention has been drawn to the management of outsourcing project. Then again, the Internet gives us several examples of successful globally distributed projects (for example Open Source projects), international collaboration and communication (especially Facebook and Twitter), and a vast amount of user generated content (for example Wikipedia and YouTube).

This contribution attempts to identify success factors of popular Web 2.0 application and transfer them to the GSS environment with the objective to suggest improvements for globally distributed software services.

In the next section the main challenges of GSS are described. The section shows that collaboration and active participation is one of the critical issues, which needs to be addressed. In addition, tools are described that are used in GSS for management and optimization of processes. In the succeeding section, factors driving the success of Web

2.0 and paradigm changes are identified. The section is followed by the application of these findings to GSS and a discussion of their benefit. The paper closes with a summary and an outlook.

2 Tools in Global Software Services

Tight coordination among the different participants in software development is required to assure project success. Curtis et al. concluded that communication bottlenecks and breakdowns are very common [CK88]. Indeed, several characteristics of software development make these coordination problems inevitable [KS90]:

- **Scale** of software projects; many software systems are very large and cannot be created or even fully understood by an individual. At least a small group is needed to conduct the task, which requires coordination.

- **Uncertainty** refers to the unpredictability of both the software service and the tasks that software engineers perform.

- **Interdependence**; software required a strong degree of integration of its components.

- **Informal communication**; understood as personal, peer-oriented and interactive communication. Formal coordination mechanisms often fail in the face of uncertainty, which typifies much software work. Under these circumstances, informal communication may be needed for coordination.

These fundamental problems of software development have been intensified by global sourcing of software services. Some arise from lack of or differences in infrastructure in different development locations, including network connectivity, development environment, test and build labs, as well as change and version management systems. Traditionally, the main focus of the information system (IS) literature has been on technical aspects related to system development projects [CK88]. Furthermore, research in the IS field has mainly focused on co-located project teams. In this respect, social aspects involved in IS projects were neglected or scarcely reported [KS90].

Global sourcing of software services can be a significant source of competitive advantage. Global sourcing means leveraging globally distributed resources. The main motivations for global sourcing are the access to competencies, resource availability and costs benefits [BH98]. Global Sourcing recently gained the attention of IT managers [HH06]. In the context of this paper, software services are referred to as all software related services such as software development, integration, and maintenance.

All software services follow an explicit or implicit software development process model. There are a number of process models such as the code-and-fix model, the stage-wise model and the waterfall model, and many more [Bo88]. The different frameworks reflect different philosophies (formal vs. agile) and scope (development vs. software life-cycle).

However, in global sourcing, the practical experience has shown that rather formal models are preferred. Hence as foundation and structure for the further analysis the waterfall model is used. The waterfall software development model is based on the following sequential phases: system/software requirements, analysis, program design, coding, testing and operations [Ro87].

All tools either support a specific phase or process chains in the software development process have been identified and analyzed. The identified tools and services were grouped and the result was the emergence of four distinct groups, which are development tools, integrated development environments, and software-as-a-service offerings. Each of these groups is discussed in detail in the following sections.

2.1 Development Tools

Development tools support one distinct phase or a specific task along the development process. The following types of tools have been identified that support specific aspects of software development:

- Document Management System: A database to store and share project related documents, e.g. MS Sharepoint, Docushare
- Testing tools: Tool supporting the testing of software, e.g. HP Quality Center, Junit
- Software Quality assessment: Tools to automatically evaluate the quality of a software, e.g. CAST, CheckStyle, EMMA
- Performance Monitoring: Tools to measure the performance of the software, e.g. Digite, Borland BMS
- Source Code Management: Central database to manage the different versions of a source code, e.g. Subversion, CVS, Virtual Safe

All these tools support a specific task of the software development process. The sophistication and the applicability of these tools can be evaluated analyzing the scope (task or process) and setting (user or team). As a result of this analysis the development tools can be distinguished into single task tools, supporting a specific task (e.g. quality assessment) and single process tools, supporting the management of a specific process involving a team (e.g. bug tracking).

However, the single task tools can be used in a globally distributed environment, but do not add any additional functionality or specifically consider the globally distributed environment. The single process tools are prepared for a distributed setting and address specific task dependent issues. The limitation is simply the focus on a specific task. In some scenarios, the value of the tool could be enhanced by integrating it into the overall process.

2.2 Integrated Development Environment

Integrated development environments (IDE) traditionally are incorporating tools such as compilers, linkers, and debuggers [HC04]. More recently additional functions such as source code management have been integrated. There can be three different types of IDEs be identified. Firstly, stand-alone IDE that are optimized for a single programmer to fulfill his task. Secondly, the enhanced IDEs supporting team features such as issue tracking and source code control. Thirdly, collaborative IDEs integrate collaboration functionality into the development environment. Collaborative IDEs offer a great range of functionalities. They are based on traditional client/server architecture in the closes environment of an organization.

2.3 Software-as-a-Service

Software-as-a-Service (SaaS) is based on the idea to provide 'software's functionality as a set of distributed services that can be configured and bound at delivery time can overcome many current limitations constraining software use, deployment, and evolution' [RG05]. The main advantage of using a SaaS solution to support the development process is the centralized development environment for the distributed team. The SaaS concept minimizes the requirement to synchronize or convert data due to the single application and single location approach.

Especially the open source community has shown that the SaaS approach can be applied to successfully develop software in a globally distributed environment. The SourceForge.net portal claimed to host a minimum of 75,000 open source projects [RG05]. SourceForge.net is a source code repository, which acts as a centralized location for software developers to control and manage open source software development and is based on the SaaS concept.

Augustin et al. identified the following differences between open source software and commercial software development: mobility of resources, culture of sharing, and peerage [AB02]. Just as well, commercial issues of software development (approval processes, extensive management reporting, resource allocation, etc.) are not considered.

2.4 Summary

This section described existing tools that are used to manage and optimize GSS. Three different categories have been identified: integrated development environments, development tools, and software-as-a-service. All tools follow one of the following objectives:

- Optimization of the overall technical development
- Support of technical development
- GSS optimization

GSS lead to new requirements. Development tools and IDE have not been primarily developed to be applied in this setting. Collaborative IDEs offer much of the required functionality and consider key challenges of GSS. However, the traditional client/server architecture does not fully support global distributed teams. Very often the collaborative IDEs are set-up in the high-security IT area of a company, and cannot be reached by external parties. In addition, the management of roles and rights in terms of the sourcing relationship is not adequately reflected. The focus of these tools is clearly set on the technical development. SaaS and thereby the concept of a shared development environment promises to solve major issues in GSS development. Shared best practises among the users of the service could further optimise globally distributed software development.

In summary, tools for GSS face new requirements that need to be addressed. The introduction of a new application in a multi-application environment, which can be assumed on the side of the client and the service provider, will be faced with acceptance issues. Nevertheless, a shared GSS platform that is reluctantly used has little value and does not achieve the objectives. Avoiding these issues, it is suggested to learn from the increasingly successful socio-semantic web applications.

3 Development of Web 2.0 and the Socio-semantic Web

Web 2.0 services are "reshaping online communication and collaboration patterns and the way how information is consumed" [HM06]. According to Nielsen survey the most popular Web 2.0 website are Facebook, YouTube and Wikipedia [Ni06]. The tremendous success of these services, Facebook has more than 400 million users [Fb10], Twitter has 100 million users with an average of 55 million tweets per day, and Wikipedia records an astonishing 16.8 million page views per hour [Wi10].

The user acceptance of these services is unquestioned.

The commercialization of Internet services started with the ARPANET. The original purpose was to create a network that reliably connects computers to aggregate distributed resources in form of servers. This first phase of computer networks has been followed by the advances of HTML and the HTTP.

In this second phase, the main objective was to connect information. The HTML allowed to link content located on different servers.

The 3rd phase of the Internet development addressed people, and linking people. Started in 2000, first social networks were established that put the user in the focus of attention. Examples of these kinds of services are MySpace, Second World, and many others.

The first social networks were followed by specific communities addressing students (StudiVZ), businesses (Xing formerly OpenBC, LinkedIN) and many others services. Today, certainly Facebook has emerged as the most popular one on a global scale.

However, starting in 2007 services was established to give meaning to any kind of content based on the underlying social network. Those services did not primarily focus on creating new content, they rather added value to existing content, by means of recommendation, linking, tagging, evaluating. For all these services the true value of meta data originates from the social network. The developments described in this chapter are summarized in the following figure.

Today, the most successful Internet services can be associated to the socio-semantic web.

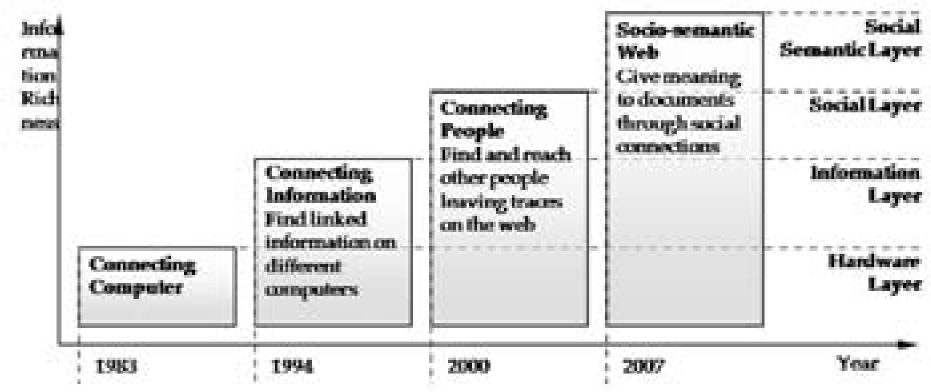

Figure 1: Development of Internet services[1]

3.1 Social Media Sites

Nevertheless, this does not result in different sites offering the same services. Different forms have been established to satisfy the users' needs to be part of a social network and share relevant content. These sites, Agarwal et al suggested the term "social media sites", can be distinguished into the following seven categories [AY09].

[1] Special thanks to Lars Kirchhoff (see Acknowledgement) for providing this unpublished figure.

Category	*Social Media Sites*
Blogs	Wordpress, Blogger, Blogcatalog, MyBlogLog
Media Sharing	Flickr, Photobucket, YouTube, Multiply, Justin.tv, Ustream
Micro Blogging	Twitter, SixApart
Social Bookmarking	Del.icio.us, StumbleUpon
Social Friendship Network	MySpace, Facebook, Friendfeed, Bebo, Orkut, LinkedIn, PatientsLikeMe, DailyStrength
Social News	Digg, Reddit
Wikis	Wikipedia, Wikiversity, Scholarpedia, Ganfyd, AskDrWiki

Table 1: Social media sites

These seven categories are the foundation for the further analysis. The objective is to identify for each category the critical success factors and mechanism to facilitate the user participation. To achieve this goal each category is analyzed in terms of:

- Objective,
- Challenges,
- Solution approaches,
- Evaluation of the approaches.

Blogs are basically diaries. Everyone can start writing a blog. The main challenge is to receive enough attention and increase the stickiness of the blog. RSS feeds have been used to lower the barrier of following a specific blog. Through the RSS feeds it became possible to subscribe to a blog and easily follow updated. Integrated into traditional Personal Information Management (PIM) clients or the usage of RSS clients automatically presented updates to the user. An additional mechanism was the integration of the visitor by comments and ratings. Content is not anymore passively consumed, but directly enriched by the feedback of the user. As a result, content that is higher rated, more viewed, and more commented, is perceived more relevant.

Media Sharing are platforms that facilitates sharing of any kind of media (e.g. video, pictures, music). Important aspects besides the ease-of-use (everyone can use those platforms) those platform offer audience. Participation is facilitated by specifically organizing content linked to users. Just by offering to subscribe to a user's channel the user is motivated to provide more content to his or her audience. Even though, Internet is far from becoming a mass media, especially video sharing platform have created some international stars.

Micro blogging is a scaled down version of traditional blogs. Micro blogs and specifically twitter have limited a blog entry to 140 characters to force the users to rethink their content better. These messages are organized in channels and any user can subscribe to these channels. Relevant messages can be re-tweeted and moved to the own channel. Since the messages are very short and micro blogging services are in general very easy to use, there are literally no barriers to create an entry.

Social bookmarking services allow exchanging web site links. The link collections are used to identify similarities between link collections of users to suggest relevant links. In addition, users can subscribe, rate, and comment collected links of other users.

Social Friendship networks are communities that focus on user networking. Typically, a user can create a profile and connect to other users. Around some communities complete eco systems have been established to benefit from the network. As an example, on Facebook applications can be shared amongst friends, e.g. quizzes, personality checks, but also multi-user games. Other networks explicitly try to create links to the real world, by organizing real-world event (e.g. Lokalisten arranges parties and Xing business conferences).

Social News is based on news published by traditional news publishers. These news are taken up and rated and commented. The main objective of these services is to discover relevant news.

One of the best known services is the Wikipedia, representing Wikis as a platform for crowd sourcing. Originally, Wikis were an electronic board everyone could write on. Everything was immediately available to other users, which could change, correct, modify, or even delete entries. The whole process was transparent to anyone. The initial reasoning behind Wikis was that a large enough crowd could create high quality content by pure peer review. Unfortunately, commercial or political forces misused Wikis as a neutral platform and used it for their purpose. As a result a core team on Wikipedia was established as a last quality instance.

3.2 Layer Model of Social Media Sites

There are two principles that all services have a common: the foundation on a social network and user generated content. Social network means that users can present themselves, connect to each other, and share information. User generated content is content (any format, e.g. videos, texts, comments, feedback, evaluations, tweets) that is created by users can create and present any kind of own content.

The way of implementing these functions, the integration of additional unique functions, and the marketing positioning of the services different the service and decides on the commercial success. However, the value of all services depends on the size of the supporting community. The more users are actively participating, the higher the potential commercial success of the service.

The following figure summarizes the findings of the previous chapter.

Figure 2: Layer model of Social media sites

The figure distinguished between three layers. On the top layer, the application, layer the feature, functions, and the design of a social media site is defined. On the second layer, the value creation layer describes the sources of value creation. For Social media sites the main source of value is the content. This content is enriched by meta data. The third layer, the business support layer, provides the functions needed to realize the user benefits. There are basically two approaches: the collaborative filtering of content using existing meta data or social network analysis. Social network analysis connects content based on the user linked to the content. There are different ways that a user is linked to content by creation, evaluating, recommending, commenting, accessing or any other mean interaction. The type interaction determines the quality of the link.

However, all social media sites are based on a social network. The social network is in all observed cases the foundation of value creation and facilitates the active participation.

3.3 Lessons learned regarding User Participation

Main objective of all social media sites is the active involvement of the users. The following lessons learned summarize the results:

- Providing a social context: A social network, and thus providing an audience to present their selves leads to active involvement, even though the attention is limited to a small percentage of users.

- Providing relevant content: Relevant content is critical. The relevance for a user is not necessarily depended on the interest for a specific topic; equally the relevance could be triggered based on the judgment of other users.

- Ease-of-user is key: Simplification and reduction to the minimum lowers the barriers to participate

- Centralization of functions: Successful sites combine different functions and allow access through a single interface. An ecosystem around the core services is established.

In summary, this chapter described the development of the Internet from a computer network to a socio-semantic Web. Different applications were the foundation to identify underlying mechanism and critical success factors for user participation. As a result lessons learned have been deviated. In the next step, it is analyzed if these lessons learned can be applied to GSS to improve productivity and quality of service provisioning.

4 Next Generation of Tools for GSS

There are reasons to believe that GSS can benefit from recent Web 2.0 developments. Since it is expected that tools will increasingly determine the management of GSS, this chapter should be understood as a requirement analysis to improve these tools. Current collaboration, governance, and management tools used in GSS neglect social aspects. The prior identified lessons learned seem to be an interesting enhancement or modifications to existing solutions.

The discussion in the following chapters is based on the four key areas identified. For each key area the status quo is described and a suggested improvement. The advantages and disadvantages of the suggested improvement are then discussed.

4.1 Providing a social Context

Collaboration tools in general lack user acceptance especially in an inter-organization settings. By providing social network functions, users are motivated to use tools. Emotional benefits (such as curiosity, peer control) draw people into tool usage and increase acceptance.

The benefits of leveraging the benefits of social networks are:

- Motivating participants to collaborate – already a photo of a remote working employee lowers the barrier to contact a team member.

- Linking knowledge to persons – simplification of the information retrieval

- Analysis of social networks to identify organizational weaknesses

- Facilitating informal communication by linking the people and offering a platform for informal exchange

However, there are some issues that need to be considered. In some cultures private life is strictly separated from working life. In an international environment this aspects needs to be considered. In practice it means, it is recommended to not rely on an open social network but rather prefer a closed system. A closed system allows the open communication of (even confidential) information and to clearly separate the work profile from the private profile.

In addition, the actually development environments or at least the governance systems should be connected to the social network to connect formal with informal communication platforms.

4.2 Providing relevant Content

In each large-scale GSS project a kind of information system is in place. They all share the same challenge of active user involvement. Traditional systems put the data in the center of attention rather than the needs of the user. Users providing and or retrieving information have specific needs. Users want to minimize the effort and maximize the benefit. One approach to achieve this is to link both processes. By the amount of information a user enters into an information system, the information the relevance of the retrieved information is improved. The process is implemented transparent that the user is aware about the connection.

The benefits of providing relevant content are:

- Decreasing the search time for specific information
- Improving the quality of the product and productivity of development by sharing knowledge, objectives, and project situation
- Facilitating the participation by a positive perception of the system, increase the willingness to provide information

The main challenge of implementing this feature is that a certain amount of data is required. Without enough data neither relevant information could be available nor enough information to deviate the relevance. Nevertheless, by offering basic subscription mechanisms to information channels (based on author, topic) the active participation can increased.

4.3 Ease-of-Use

Software development is one side increasingly simplified and on the other hand the management and governance of software development continuously formalized. Application Lifecycle Management tools are supposed to manage the overall lifecycle from the initial business idea to the software deployment and maintenance. Companies use these tools to be capable to manage the organically grown complexity of their application landscape. However, ALM tools collect a vast variety of data during the development process and expect decision in early stages that are not directly related to the development task, but the later deployment. Many developers, and especially in a globally distributed setting, are just overwhelmed by this complexity.

Thus, instead of increasing complex systems that can fulfill requirements of all stakeholder and potential organizational and development models that need to be configured to the actual project needs, a simplified tool is expected to be the better solution.

The benefits of ease-of-use:

- Minimizing the effort of localization and translation of an application
- Minimizing costs for training and configuration of a complex application
- Improving productivity to reduce overhead that not necessarily pays back
- Regarding communication, instant messaging and tweets are two examples of informal communication tools that follow the ease-of-use principle.

Despite the improvement of ease-of-use, the purpose of the application should not move out of scope. Certainly the main challenge will be to strip down functionalities and features without losing required functions.

4.4 Centralization of Functions

The centralization of the service has besides the operational benefits (maintenance) advantages for the users. The organically grown internal application landscape of major companies can cover some hundred applications. At least a dozen a required for day-today work. Already keeping the own information updated in these applications is a day's work.

The benefits of a centralized platform:

- Improving productivity of the user, avoiding redundant data bases
- Cost savings based on reduced system and application operations
- Improving traceability

There are two aspects that need to be considers: data privacy on a user level and data protection on the company level. The connection of all different systems can be used to control and evaluate users in form that is legally not allowed, ethically wrong, and commercially questionable. This type of data gathering and profiling must not be supported. In addition, a centralist provisioning of a development environment needs to consider outsourcing scenarios in which third parties are accessing the system. This requires a sound role and rights system.

5 Summary

This paper started with the challenges of GSS and the commercial need to improve GSS. Successful mechanisms of the Web 2.0 worlds were identified (social network, relevant content, centralization, and simplification). The status quo in each of these key areas is described and potential benefits and expected disadvantages of an implementation are discussed. In summary, without a doubt existing tools do not yet take advantage of socio-semantic mechanisms. The expected benefits especially regarding productivity and quality justify an investment to enhance existing tools.

However, this paper does not describe a particular tool fulfilling these requirements. It rather shows a new direction and focus that should be considered in tool development. We invite everyone to take on the discussion on the appropriateness of the approach.

Acknowledgement

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Optimization of Service Delivery through Continual Process Improvement: A Case Study

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Abstract: In order to deliver services of high quality in a cost-effective manner, processes and their support through information technology (IT) play an increasingly significant role. We present an approach, which allows optimizing the service delivery through continual process improvement. This approach combines the 7-step improvement process recommended by ITIL with process mining. On the basis of suggestions derived from process mining, performance indicators of different services are determined and subsequently compared as part of an internal benchmark. The approach, which will be trialed in practice, enables the optimization of service delivery certainly, but it is also concerned with the most effective utilization of limited resources in terms of people and tools.

1 Introduction

Today IT service providers (ISPs) face the pressure to deliver high-quality IT services in a highly competitive and fast-moving environment. Quality enhancement and cost reduction, therefore, have become mainstream thinking. As a result of the pressures, ISPs are advancing the improvement of their IT service management (ITSM) processes and making use of reference models. ITIL, for example, is among the most used frameworks of service delivery [AS+08]; it provides guidance that enables organizations to create and maintain value for customers through better design and operation of services.

After the processes have been (re-)designed according to the reference model it is necessary to continuously check process execution. In order to identify possible quality problems, organizations commonly measure the efficiency and effectiveness of their ITSM processes with key indicators. Target value verification allows analyzing whether the reaching of a process goal might be jeopardized.

Building up such a measurement system involves a purposive definition of indicators. The definition, however, seems to be difficult for a variety of reasons. First, no organization knows the optimal set of indicators in advance and, with that, has difficulties in articulating them. Furthermore, such specification in advance results in a selective monitoring process, which appears to inevitably limit control and improvement opportunities (i.e., important relationships are left unmonitored and remain hidden). Second, as a reflection of the business strategy the metrics for process monitoring should adapt as the strategy and/or underlying goals change. Already Morgan and Schiemann (1999) [MS99] stressed that metrics, which are outdated or lack the alignment with organizational objectives, could even block the benefits.

The situation is further complicated by the fact that the degree of automation in the active handling of ITSM processes is still unsatisfying. Key sources of problems are missing or unexploited tools between the various perspectives and the various stages in the lifecycles of processes. The gap between normative modeling for compliance purposes and the actual execution of a workflow provides a pertinent example. In this context, process mining facilitates the automatic analysis of processes by deriving the process knowledge from event logs, which have been recorded during the execution of ITSM processes.

In view of the significance of ITSM processes, we have developed an approach for the purpose of continual process improvement (CPI) [GPT10]. The approach integrates process mining and the 7-step procedure recommended by ITIL into the ITSM process. In order to optimize the delivery of IT services to customers and users, two additional important topics need to be treated properly nevertheless: The first issue is the most efficient utilization of limited resources in terms of people, systems, and documents. The second issue arises from the fact that different services share the same IT process. Obviously, we need to prove if these processes hold for service-specific peculiarities.

Since process mining aims at revealing hidden process information, a further question emerges, namely whether this capability can be used to dynamically propose performance indicators, which hint at service improvement potential.

The contribution that our study makes is twofold. First, we present a case study of an incident management process of a German ISP, which enables us to verify the CPI approach with respect to the effectiveness of processes. Second, the case study enables us to theorize about the effects different services have on ITSM processes, resources, and tools. The result is a further development of the CPI approach.

In light of this background, the following section starts explaining the existing possibilities of process improvement based on ITIL and process mining. Section 3 reviews related work. Then, Sect. 4 applies the CPI approach in practice. Afterwards, Sect. 5 describes the research implications reached from the case study. Finally, this contribution addresses central conclusions and future research directions.

2 Continual Process Improvement in Concept

This section provides a broad overview of the contribution of process mining and ITIL to service improvement for the remaining sections of this paper.

2.1 Service Improvement according to ITIL

ITIL was originally developed on behalf of the British government by the Central Computer and Telecommunications Agency, which is now incorporated by the Office of Government Commerce. ITIL describes an integrated best practice approach to managing and controlling IT services. The content is depicted in a series of five books, which embrace the entire lifecycle of IT services: Service Strategy, Service Design, Service Transition, Service Operation, and Continual Service Improvement. Since we will adapt the procedural model of ITIL, we will introduce the processes within the lifecycle Continual Service Improvement in detail. For reasons of space, we refrain from presenting the remaining lifecycles and refer to the respective books[1].

According to the book Continual Service Improvement it is essential to compare defined measurements with expected results. The comparison reveals those elements of process, which prevent from meeting the expected objectives effectively: The verification of key goal indicators (KGIs) determines whether process goals will be reached [IG07]. Key performance indicators (KPIs) display whether process performances endanger the reaching of a process goal. The ongoing confrontation between to-be and as-is condition is executed in seven steps [TCS07]:

(1) Define what should be measured: Root objectives and success factors are defined.

(2) Define what can be measured: In order to keep to the measurable points, organizations need to consider limitations (e.g., resources, budgets) on what can actually be measured.

(3) Gather the data: The data is selected, which serves as the origin from which deviations can be identified and explained.

(4) Process the data: The processing of the data refers to those operations, which are essential for the analysis (e.g., formalizing data).

(5) Analyze the data: Measurements are compared with expected results to reveal those elements, which prevent from meeting the expected objectives effectively.

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1 www.itil.org

(6) Present and use the information: The information is communicated to business, senior management, and IT to derive corrective actions for implementation.

(7) Implement corrective actions: The actions necessary to improve services are implemented.

2.2 Process Mining

Process mining is a method which automatically infers the general process knowledge from a set of individual process instances (i.e., cases). Generally, the execution of these instances is recorded by ISs and stored in event logs. The event logs are then formalized in the Mining Extensible Markup Language (MXML) format [DA05], which is required by the process mining algorithms [RVA08, MWA06] available in the process mining framework ProM[2]. These algorithms use the event logs as a starting point to derive the implicitly present knowledge in the form of a process model.

Process mining has many benefits. First, it reveals information as to what, how, when, and where something was done (i.e., process discovery). The primary goal strives for understanding what is actually happening in the organization. Second, process mining can be used for compliance checking, that is, comparing the current way of working with the way it was agreed upon [RJGA09]. Thus, as-is processes may be analyzed with respect to weaknesses and improvement potential. Finally, process mining supports the analysis of process performance (e.g., bottlenecks in the way of working).

A major drawback of process mining is that it can only be transposed to case-oriented processes. A case consists of a sequence of activities between which relations of dependence exist.

2.3 Integration of ITIL and Process Mining

Figure 1 depicts an approach to continually improve ITSM processes as proposed by Gerke et al. [GPT10]. In the first phase, each ITSM process is continuously monitored as part of the processes execution. The role of operational monitoring is to ensure that the ITSM process functions exactly as specified. This is why the first control cycle (CPI 1) is primarily concerned with target verification and the compliance of the as-is processes with to-be processes. This control cycle inherits steps three to six of the 7-step procedure. All steps are supported by process mining techniques, which allow automatically measuring, comparing, and alerting the meeting of the to-be specifications.

Once the process identifies a likely deviation, the second phase is triggered. The second phase (CPI 2) can be continually applied in a semi-automated way. It passes through all steps of the underlying 7-step procedure. The phase is initiated by four types of changes. First, changing business requirements might entail adapting the design and the implementation of the to-be process model. Second, the changes can be initiated by the

[2] http://www.processmining.org/

identification of deviations between both key indicator values and their target values or between the as-is process and the to-be process model. Third, the further development of the reference model (i.e., a new version) can trigger the changes. Finally, the approach supports the ex-post control of measures taken according to the intended success.

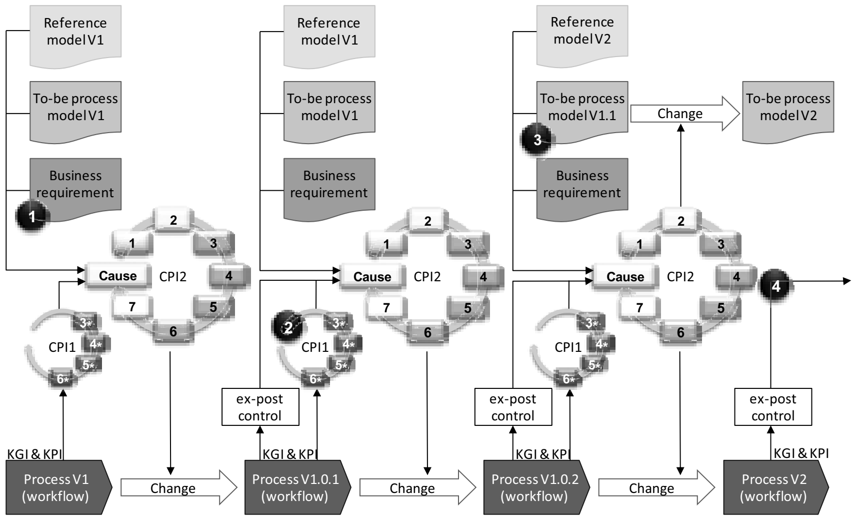

Figure 1: Continual process improvement approach [GPT10]

3 Related Work

This section investigates views of other researchers into the discussion of process improvement. The existing sources can be grouped into three categories: analysis of event logs, process controlling, and data warehousing.

3.1 Analyzing Event Logs

Our contribution can be related to the mining of processes in the business context. There is a growing body of knowledge, which reports on case studies in different application domains. They resemble in that they all describe reverse engineering with process mining from event logs. Mieke et al. [MLV08], for example, analyzed the procurement process for the purpose of internal fraud risk reduction. Rozinat et al. [RJGA09] investigated feedback loops and the idle times of a test process of scanning to identify concrete improvement suggestions. Măruşter and Beest [MB09] proposed a methodology comparing the mined model with a simulated model to predict potential performance gains for redesigning business processes.

This paper extends our previous work as presented in [GPT10]. Rather than only focusing on improving the effectiveness of processes, we broaden the approach with respect to resources and service-specific characteristics. Since only a few researchers have investigated the question of how to integrate the continuous improvement process and process mining techniques into ITSM processes, this topic is little understood so far.

3.2 Process based Controlling

Well-known controlling and performance measurement systems, such as the balanced scorecard [KN92], Six Sigma [BR06], etc. support the evaluation and the monitoring of processes in order to improve the processes. The process of building an objective indicator-based measurement system, however, requires a deep understanding about the relationship between processes, target values, maturity levels, and corporate goals. This is the reason why organizations face the challenge of determining relevant indicators. In contrast, our approach provides guidance on automatically selecting statistically significant KPIs.

3.3 Applying Data Warehouse Concepts

Process improvement based on event logs can be seen in the context of business process intelligence. Few authors, such as zur Muehlen [MU01] or Casati et al. [CCDS07] discussed the design of data warehouses, which take advantage of event logs as an information source. It should be noted that due to challenges in storing and modeling the *process warehouse*, there are still open issues (e.g., the integration of business data) requiring further research. Because of the unresolved issues, the aforementioned works presented are limited to theoretical approaches or prototypical implementations.

4 Case Study

In order to deepen our theoretical understanding of continual process improvement, we carried out a case study of the German telecommunication industry. The relations in question are twofold. First, we want to understand the effects that different process variants (i.e., services) have on ITSM processes, and second we want to comprehend the influence of people, systems, and resources.

4.1 Methodology

We chose the case study method as a qualitative research method because it enables us to analyze a contemporary phenomenon in its real word setting. In addition, it represents a means of collecting and analyzing data to gain a comprehensive and in-depth understanding of the situation present. Therefore, we believe that the case research method is well-suited to capturing the knowledge of practitioners and developing theories from it. As is true for any case-based analysis we cannot entirely overcome the inherent unreliability of generalizing from small samples, but the fact of having more depth in the analysis dominates on the positive side [Fly06].

4.2 Process Description

We analyzed the incident management process of a German ISP for its IT service production. The ISP manages incidents and service requests via a service desk. After a service request has been reported, a ticket is opened in the Workflow Management System (WfMS), which is initially handled through the incident management process. The ticket is passed through various processing steps until the incident is disposed or the problem is resolved and the ticket can be closed. In general, the processing consists of the steps *Receive Incident*, *Categorize Incident*, *Analyze Incident*, *Resolve Incident*, *Assure Quality*, and *Close Incident*. During the ticket flow, the WfMS stores information of the actual processing status as well as the corresponding time stamps in a history of action. In addition, the support groups involved with the incident handling will fully document all details of any actions taken, such as the originator of the action, the affected service, as well as the solution statements, and if applicable, cross references to master and slave tickets.

From a large set of services we selected the services to which we refer to as S_1, S_2, and S_3. These services are not revealed due to nondisclosure agreements. The services embrace various aspects, henceforth referred to as differentiators. First, the routing of the incidents within the workforce involves different responsible support groups. Second, the complexity of the underlying ITSM process diverges significantly due to the collaboration to external supply chain partners. For example, the ISP engages the services of a carrier who provides the cable network to offer the service $S_{3.}$ Instances can, therefore, be caused either by the ISP or the carrier. Consequently, we can classify service S_3 as the most complex service.

4.3 Continual Process Improvement in Practice

Turning now to our use case we apply the CPI approach as described in Sect. 2.3.

Definition of what should be measured: The incident management poses a serious challenge to the ISP to restrain from having a negative impact on user experience. To ensure an effective incident management, the service operation follows ITIL. However, it needs to be analyzed whether the process implementation is effective for all services. Furthermore, the efficient utilization of resources is a precondition for successful cost control.

Definition of what can be measured: Incident management for each of the services S_1, S_2, and S_3 is implemented based on the reference process model. Statements on the efficiency and effectiveness are based on comparisons of the respective workflows as part of an internal benchmark. The histories of action recorded by the WfMS are the basis from which the as-is processes and a metric of performance can be derived. The processes and the performance values can subsequently be contrasted to each other.

Gathering of the data: We selected incidents, which were completed within a specified time interval according to the criteria, which we have already described in the use case description. The information about the incidents stems from the history of action.

Processing of the data: The gathered data was converted into the MXML format by a custom-built converter plug-in for ProMImport[3]. The event log of S_1 was made of 1.816 cases, that of S_2 consisted of 4.182 cases, and that of S_3 comprised 6.070 cases.

These event logs serve as input parameter to the process mining algorithm Heuristics Miner [WAA06]. The resulting heuristic net uses rectangles to represent single activities, the current status, and the associated frequency of occurrence. The rectangles are connected via directed arcs visualizing the dependencies between activities. The upper numbers next to the arcs illustrate the absolute occurrence, whereas the lower numbers indicate how confident we are that the dependency exists. The closer the number is to 1, the stronger the relation is. As the event logs start and end with various events, two artificial events *ArtificialStartTask* and *ArtificialEndTask* indicate the start and end of the process. The left-hand side of Figure 2 shows model S_2; the right hand side depicts model S_3. The models look different at first sight certainly, but a closer look shows that they have common ground: same activities, similar starting activities, and similar routing.

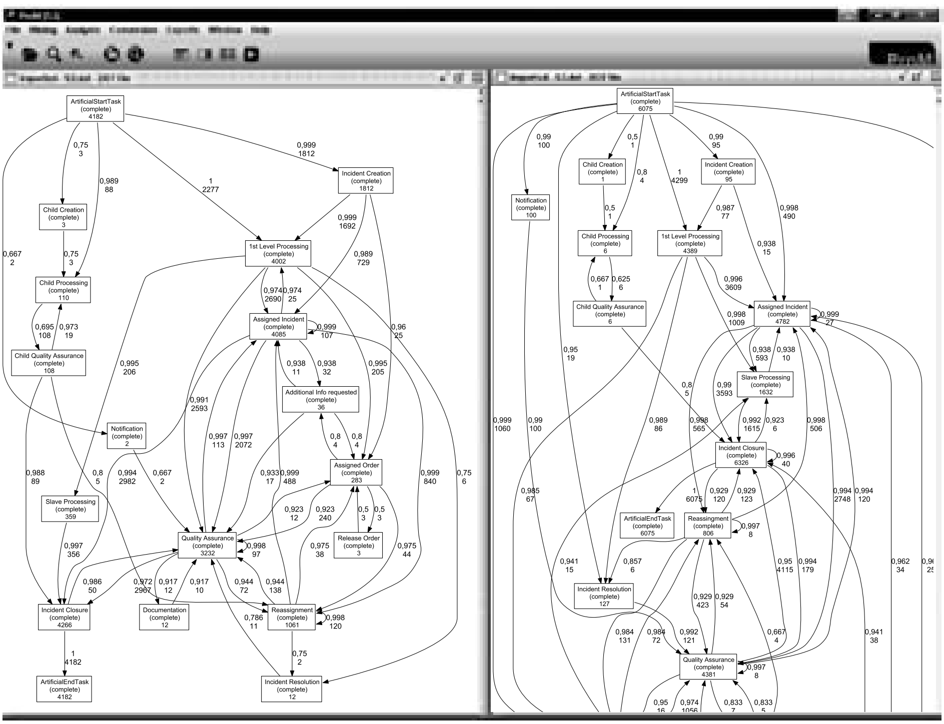

Figure 2: Process models derived by process mining

To assess the quality of the mined models, the continuous semantics fitness measure (CSF) [WAA06] calculates how precise the model actually covers the observed behavior in the event log. The measure results from replaying the activities in the event log. The

3 http://prom.win.tue.nl/research/wiki/promimport/start

closer the value is to 1, the better the quality is. The CSF of the models yields high values of 0.97 (i.e., S_1), 0.72 (i.e., S_2), and 0.88 (S_3), and with that a fairly well representation of the incident handling.

The event log further serves as input for a table where all process activities and their absolute (#) and relative (%) occurrences are listed. Condensing the information from S_1, S_2, and S_3 makes a statistical analysis of the data possible. The functions mean and standard deviation (SD) provide the statistical relevance. Table 1 shows an excerpt of the complete quality indicator list.

Activity	Occurrence						Mean	SD	Range	
	S_1		S_2		S_3					
	#	%	#	%	#	%			From	To
Assigned Incident	1,388	76.40	4,085	***97.70***	4,905	79.40	84.50	11.5	73.02	96.02
Incident Closure	1,815	99.94	4,182	100.00	6,172	99.95	99.90	0.0	99.94	100.00
Incident Resolution	8	0.40	12	0.30	129	***2.10***	0.97	1.0	-0.06	1.94
Reassign-ment	238	13.10	1,061	***25.40***	857	13.88	17.50	6.9	10.58	24.32
Quality Assurance	1,489	82.00	3,232	***77.30***	4,413	71.50	76.90	5.3	71.64	82.19

Table 1: Excerpt of the indicator-based measurement system

The information of this list is made comprehensible by gradually narrowing it down to a specific sample of KPIs. The selection process corresponds to the funnel method and is depicted in Figure 3.

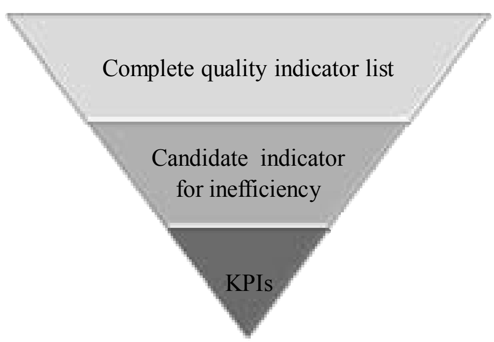

Figure 3: KPI selection process

The highlighted values in Table 1 propose those indicators, which hint at inefficiencies and with that, need further inspection. The values were highlighted because they are outside the range, which was computed by mean ± SD. As a result of the selection process, the KPIs Assigned Incident, Incident Resolution, Reassignment, and Quality Assurance were selected.

The processing of the data as described in this section can be executed for all candidate service differentiators (e.g., support group), so that we extract a hierarchy of models and corresponding tables of performance indicators.

Analysis of the data: Upon inspection of the table it can be diagnosed that the performance values partially deviate strongly from those of different services. Limits of space only allow us a detailed description of three KPIs.

Take, as an example, the beginning of the incident processing. We refer to this example to as DEV1. We consider the indicator *Assigned Incident*, which expresses that the service desk staff was unable to resolve the operational problem themselves and assigned the incident to the next appropriate level for further inspection The only slight increase in the frequency in S_3 compared to S_1 (79.4% as against 76.4%) indicates the similarity of the two services. Unlike S_1 and S_3 the activity is observed with 97.7% in S_2 and, with that, exceeds the average 1.14 standard deviations.

It is interesting to note that the indicator *Assigned Incident* influences the KPI 1st kill rate, measured in the traditional measurement systems of the ISP. Just as the number of incidents which are released by the service desk increases, so does the 1st kill rate. Depending on the complexity of the service, however, it is possible that the organization is not striving for the highest possible 1st kill rate. One possible reason is that it is too expensive to build up the necessary knowledge among the employees. As this is the case for S_2, the ISP accepts a lower 1st kill rate for service $S_{2.}$

Now let us consider the indicator *Incident Resolution*. The activity represents the resolution of incidents in which a third party is involved. In services S_1 and S_2, the activity is present with relatively low frequencies (0.4%, 0.3%) – as against 2.1%. in S_3. Statistically spoken, S_3 differs from S_1 and S_2 by 1.15 standard deviations. To put this into perspective, we look at the underlying collaboration in S_3. As above mentioned a telecom carrier is additionally involved in the delivery of service $S_{3.}$ Since the resolution of incidents is more complex, the deviation, hereafter termed DEV2, has its origin in the complexity of service S_3.

The activity *Reassignment* is designed to redirect wrongly assigned incidents. According to specification this activity is, therefore, provided only by exceptions. It is noteworthy that the execution of this activity in S_2 exceeds the average 1.15 standard deviations. To understand the deviation, hereafter abbreviated DEV3, we fell back upon the process models and drilled down to the group specific models. The table of these models revealed that the infringement of working procedure was prompted by a couple of support groups. This fact induces us to judge that this deviation results from resources, notably missing knowledge.

Summarizing, we found deviations particularly in S_2 and S_3. We identified deviations, which are either inherent to the nature of the service, that is DEV1 and DEV2, or stemmed from improvable resources, namely DEV3. The services under observation are distinct in terms of resources and complexity. The factor resource in DEV1 and DEV3 differs in the way that the former is a suboptimum, which the ISP accepts when looking at the service in its entirety, and the latter needs to be improved to optimize the service delivery.

Presentation and utilization of the information: We determined the measures necessary to optimize the service delivery in a series of workshops within the organization. In view of the increased transparency of service-specific characteristics, the ISP considers the utilization of the CPI approach in further process domains.

Implementation of corrective actions: The corrective actions are twofold: first, closing the gap of knowledge, and second a change in the comparison base of process mining. The former will be sealed with training for the users. The latter is required since the ISP accepts the service-specific characteristics in the process.

Together with the responsible process manager, we also verified that the use of the CPI approach clearly enables a growing maturity of the ITSM processes and, with that, an optimized service delivery.

5 Research Implications

One important conclusion we can draw from the use case is that one deviation is not like the other. Some deviations can be justified by peculiarities inherent to the services, whereas others stemmed from deviant working behaviors. Therefore, we distinguish between deviation patterns, which are led back on weak points either in the process or in the process implementation. We refer to the former as *Reference Non-Adherence* (RNA) and the latter as *Reference Adherence* (RA). As the CPI approach is only aware of structural deviations, that is pattern RNA, it has to be extended as depicted in Figure 4.

Step five of the control cycle CPI 1 includes a pattern analysis for making the appropriate determination of whether a problem lies within the process or within the process execution. In case of pattern RNA the process deviates from specification as a result of which the CPI approach is continued as originally developed.

The determination of pattern RA, however, triggers the control cycle CPI 2b. The rationale behind this cycle is that the process still optimally supports the business but has to be improved service-specifically with respect to the actual implementation. The semi-automated analysis is done by control cycle CPI 2b, which consists of all steps of the 7-step procedure. It is important to note that the analysis of the deviation (i.e., step three to five) is carried out in an automated way; it is supported by means of process mining and results in a measurement system, which in conjunction with the process model supervises the complete process course and identifies statistically relevant KPIs. It is, therefore, not necessary to determine KPIs in advance.

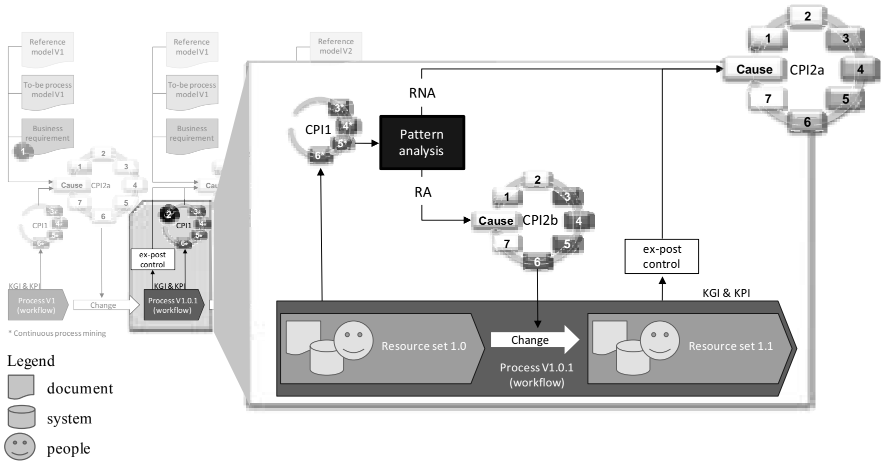

Figure 4: Extended CPI approach

The analysis of the KPIs can be particularly made with respect to distinctive features of the process in order to detect the sources of the deviations. Examples of possible differentiators are services, spheres of responsibility, cooperation models, or resources. If a deviation is due to process execution, two candidate solutions are available. First, it is not necessary to change the process itself but rather initiation of a resource or service-specific improvement activity (e.g., additional training etc.) might be more recommendable. The activity changes the resource set in terms of people, systems, or documents. Cycle CPI 2b continually repeats itself until the performance indicator is within the normal range again, that is, an efficient resource set with respect to the internal benchmark is found.

Second, the alternative decision is to accept the deviation because the supposed outlier is specific to the differentiator. In this case, the comparison base (i.e., to-be model) for process mining has to be adjusted or supplemented.

6 Conclusions and Future Research Directions

Based on our experiences in the telecommunications industry [GPT10], we have proven the validity of our approach to continually improve processes with respect to structural deviations from reference processes. The use case, however, confirmed that further deviations occur. Here are two examples: Services of different complexity require different knowledge levels. Depending on the complexity of the collaboration mode, working procedures can diverge within a process.

Because of the results from practice, we extended the CPI approach so that it provides guidance not only to comply with reference models but to identify and correct service-specific weaknesses of the process implementation. The extension integrates ITSM processes, people, and resources into the CPI approach.

We support practitioners in their evaluation of the potential of process mining. Process mining allows an objective and automated determination of the as-is condition, notably process models. The capability to reveal hidden information is particularly useful for the dynamical suggestion of performance indicators pointing to potential efficiency problems. It has to be stressed that the composition of the indicators is dynamic rather than static. These indicators contribute to an optimization of the IT service delivery as perceived by the user.

In summary, we identified various benefit potentials: First, service-specific characteristics of the incident management process are transparent. Second, the process quality can be measured and controlled through quantifiable information. Third, measurement is reproducible, repeatable, and comparable as base for improvement measures and the corresponding ex-post control. Finally, the high level of automation contributes to a good cost-benefit ratio.

In future, we will account for process variants when checking process compliance with to-be processes. A to-be model, which embraces the service inherent peculiarities, needs to be derived. It then serves as the process model against which the as-is process will be checked. We also aim to learn if it is possible to build a knowledge base as input for the pattern analysis. Information about former deviations, such as solution, type, or reason can flow in the knowledge base from which the pattern analysis can automatically classify deviations and present suggestions simultaneously to solve the deviations.

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Case Study on Extending Internet of Services Techniques to Real-World Services

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Abstract: The Internet of Services promotes distributable, composable and tradeable services as first-class entities. Such services are assumed to encompass the full range from electronic web services to conventional business services. However, research and development of service models and platforms to realise the Internet of Services vision has largely been concentrating on pure technical services. In this case study, we have applied modelling and registration techniques to existing business services with none or few technical components. We outline the results of suitability and acceptance aspects and include an evaluation of the new Unified Service Description Language (USDL) compared to the Web Services Modelling Language (WSML) in the context of real-world service representation.

1 Background

Businesses involved with e-business activities struggle to find a balance between keeping trade secrets and exposing information about their products and services on the untrusted Internet [DL02]. On the contrary, any participation in value chains backed by distributed business processes requires a public, detailed and accurate description of goods and services. The Internet of Services (IoS) idea suggests that these services become tangible entities which can be traded and composed on marketplaces to ease the creation of value chains [Car09, CBSvD09]. However, techniques from this area still differ in how they apply to technical services compared to real-world services (RWS). While today most research prototypes focus on technical web services, it is expected that the service continuum handled by IoS service platforms be extended to conventional business services over time. According to the typical service lifecycle in the IoS [OBB+ 09], differences would most likely occur during the usage phase due to missing technical service execution, while the other phases would mostly remain the same. Therefore, we conducted a case study on the extent of reusability of Internet of Services ideas and techniques especially from the modelling, registration and offering processes to real-world services. The offering phase scope of the work is hachured in the IoS service lifecycle in figure 1.

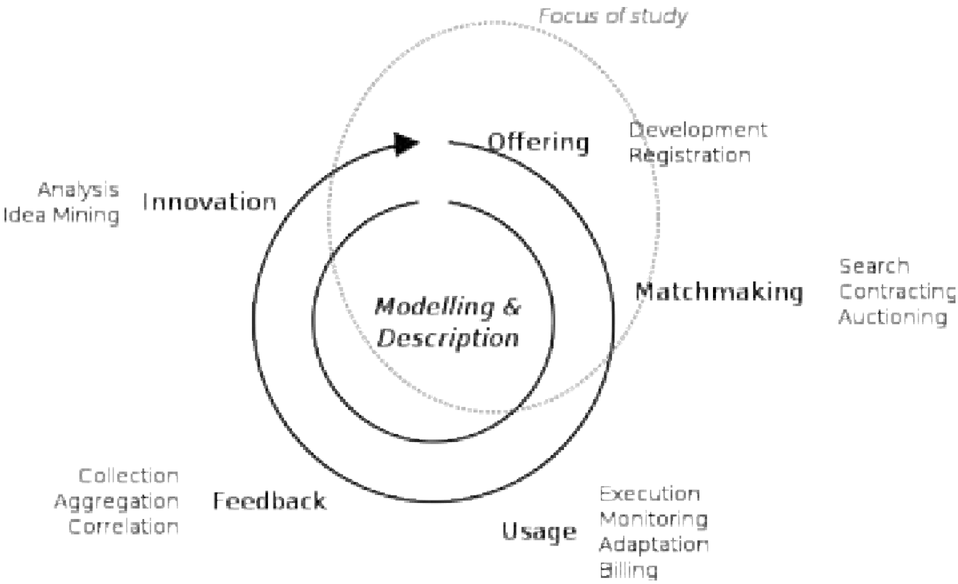

Figure 1: Scope of evaluating real-world service trading in the IoS lifecycle

Our first aim was to determine the technical suitability of modern declarative description languages for conventional business services or hybrid IT-supported services. Previous languages designed purely for web services such as WSDL and DAML-S have been criticised for not conveying enough information about the value and the content of RWS [BAG03]. Therefore, we wanted to find out which languages offer a spectral view from conventional to electronic services, thus making it possible for service providers to change the service implementation and deliv ery without having to change the description. Of particular interest has been a readiness comparison of the new language USDL specifically designed to describe tradeable business services with the established generic semantic web service language WSML. Our second aim was to see to which extent companies accept the offering processes on service marketplaces. It implies a consideration of the willingness to expose descriptive service information in registries. To reach both aims, we performed an evaluation study called Real World Services in Dresden (RWSDD) with the additional goal of extrapolating its results to a general discussion on IoS concepts.

The remainder of this paper is structured as follows: first, we present our applied multi-phase evaluation methodology including the selection of target companies and services and the steps required to bring them into the IoS. Then, we explain our findings regarding the suitability of selected service description technologies and acceptance of

our chosen approach regarding the survey, modelling and registration of commercial RWS. The methodology and the findings are compared to similar studies. finally, the paper is concluded with remarks on the prospective value of the IoS for real-world services.

2 Evaluation Methodology

The starting point for the case study is a local setting of companies offering services within the city of Dresden in Saxony, Germany. The economical-structural characteristic of having mostly small, often tiny, and only some medium-sized companies poses a challenge regarding the ease of use of Internet of Services techniques. The criteria for the evaluation of suitability and acceptance aspects in applying IoS techniques to RWS have been chosen accordingly. They encompass service identification to isolate services from the overall offering of the companies, adequate tooling to express the service concepts and constraints appropriately without overhead or under-specification, and self-empowerment to let companies model, manage and register the descriptions by themselves.

We prepared a four-phase methodology which included an identification of a decent number of various service companies, and subsequent reduction of quantity, hence gaining quality, by filtering with a questionnaire, active modelling of service descriptions and registration of the services at an internal and a public service portal. We also planned a selective implementation of web services leading to hybrid conventional-electronic service offerings although eventually decided to postpone this activity. The resulting methodology is visualised in figure 2. The timeframe for this evaluation was limited to three months from February to May 2010. It was mainly conducted by a student by e-mail in multiple feedback rounds. The following paragraphs describe all evaluation phases in detail.

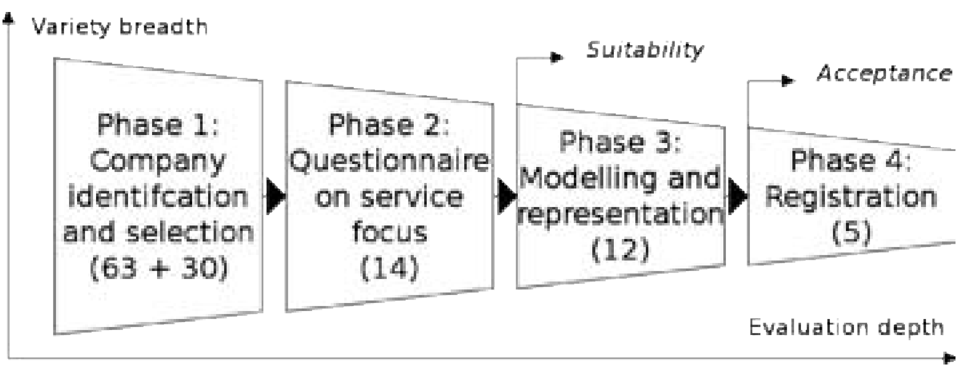

Figure 2: Overall methodology of real-world service selection and integration into the IoSin multiple phases, including number of participating companies in each phase

2.1 Identification of Service-Centric Companies

We limited our study on 63 individually identified local companies from all industry domains and in addition through an industry association (IHK) to 30 companies from the tourism sector.

The first set of companies included mostly small and tiny companies which according to their own estimations offer 95% services and 5% products. Represented industries were mainly event agencies, design studios, translation and correction of documents, consulting and delivery services. Target customers were a mix of consumers, businesses and the public sector.

The second set of companies included mostly branch offces of larger tourism companies which are characterised by a higher level of IT-supported operations. In contrast, decisions about IoS integration are less likely taken directly by the local companies. The chosen tourism companies offer travel planning and booking services, sightseeing tours as well as lodging and catering for tourists.

All selected companies were sent background information on the Internet of Services and a questionnaire about their service offering and procurement habits. The tourism companies received an industry association statement about the importance of Internet innovations as additional incentive.

2.2 Inventory of Existing Service Offering and Usage

Only 14 companies completed the questionnaire, while some filled the forms only partially. Missing key data such as company names even made it impossible to identify duplicates, therefore we dropped all incomplete questionnaires. The response rate was higher with smaller companies compared to medium-sized ones. Of note are some statistics about the companies' previous usage of Internet and World Wide Web facilities according to the results of the questionnaire. 100% are advertising on a dedicated website. 71% make use of online business registries, while only 36% are paying for inclusion in printed industry registries. Regarding the descriptions of offered services, 100% found the company name and website required attributes, compared to 64% for both the offering details and telephone contacts. Physical address information was deemed important in 29% of all cases, either as text or as geographical location on a map. Electronic services are offered by half of the companies. The statistical information served as input for the service identification criterion.

2.3 Service Modelling

Among all companies which completed the questionnaire, 12 indicated that they be interested in having their service offering modelled in a modern declarative service description language, and the remaining 2 were undecided. We started modelling with the Unified Service Description Language (USDL), while in parallel evaluating concepts from the Web Services Modelling Ontology (WSMO). The results of this phase determine the suitability of IoS service description languages and are thus presented in detail in the next section.

2.4 Service Registration

After creating the service descriptions, we submitted them for a brief review to the companies and offered them to have them registered publicly on a service marketplace, not registered at all, or registered with pseudonymisation techniques applied so that the real-world business could not easily be found out from the service description. The results of this phase determine the acceptance of IoS marketplace concepts and are thus presented in detail in the next section.

2.5 Further Phases

The questionnaire results indicated that similar to the modelling needs, 9 companies would be interested in a web service implementation regarding parts of their business services, with the remaining 5 being undecided. Our study did not cover the actual realisation of web services or any post-registration activities like search for offered services, service usage contract establishment or feedback submission.

3 Findings

Our study concentrated on two main aspects: Suitability of current service description and registration techniques, as well as acceptance of offering services at IoS marketplaces among the participating companies. We give a detailed explanation about possibilities and weaknesses of modelling RWS with USDL and WSML to determine the suitability, and we analyse the responses of companies to our realisation to determine the acceptance. We draw conclusions mostly from the 3rd and 4th phase of our evaluation. It should be noted that due to the low number of services considered in the late phases, the results are not representative. However, given the lack of similar studies, they help to understand the challenges of bringing real-world services into the IoS and to identify problems early in the process.

3.1 Suitability of USDL

USDL is a very recent service description language which has so far not yet been used on public service marketplaces [CWV09]. It presents a simplified syntactic XML representation of a hierarchically modular service ontology based on OWL [OBB+ 09]. Major modules encompass a foundation and core description, service level objectives, pricing, functional descriptions and interaction, as shown in figure 3. The syntax is kept synchronised with an Ecore model so that Ecore-based transformations can be used in addition to XML transformations, which is popular with Java tool developers [ETV06] and hence stimulates the refinement and extension through domain-specific modules and vocabulary. At the time of the evaluation study, not all modules of version 3 (USDLv3) were completed. Especially the legal module has only been created as a stub, and the service level module was work in progress. This limitation, combined with an exclusion of syntax intended to represent features of technical services, restricted our study to functional and pricing aspects. The USDL editor, while not yet easy to use, can be considered adequate for expressing all language features. A further limitation, restraining the self-empowerment criterion, was the missing unrestricted availability of the editor to companies. We worked closely together with some of the USDL authors and tooling creators to ensure that our feedback could help to avoid some of the early issues we found. The progress on USDL development can be tracked on an Internet of Services commercial community site[1]

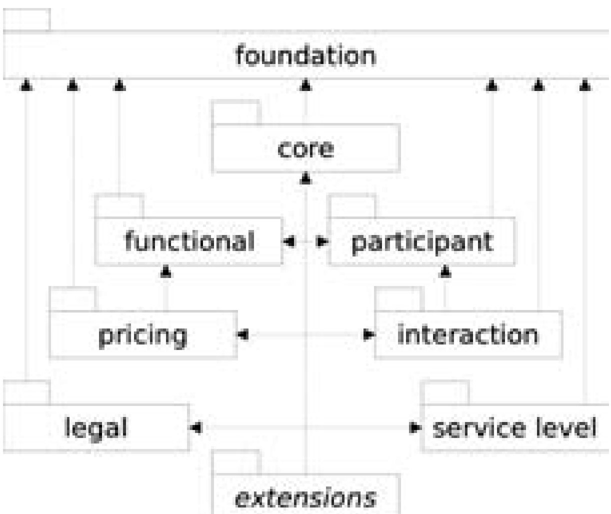

Figure 3: Modular structure of USDL version 3

In general, USDL can be seen as the first major description language which is suitable for RWS and web services alike. The example 1, which is an excerpt from one of the RWS modelled by us during the study, demonstrates how to represent an actual certified consulting service without explicit pricing information in compact USDLv3 pseudo-notation which omits syntax elements for better readability.

1 USDL community: http://internet-of-services.com

```
core : Service {
  guid "urn:Consulting Mueller Services"
  nature "Human"
  naturalPersons {
    firstName "Gustav"
    lastName "Mueller"
    contactProfiles {
      virtualAddress "+49 (351) 0000000"
  }}
  organizations {
    guid "urn:Consulting Mueller Company"
    representatives "//@naturalPersons.0"
    certifications {
      certificate "DIN ISO 9001"
    }
    contactProfiles {
      physicalAddress {
        street "Dienstboulevard"
        city "Dresden"
  }}}
  serviceLevelElements {
    availabilityAttribute {
      type "Telefonische Erreichbarkeit"
      timeZone "CEST"
      timeRanges {
        Mo-Fr: 9:30-16:00
    }}
  }
  paymentTerms {}
  pricePlans {
    name "Standardstundensatz"
    currency "EUR"
    planComponents {
      componentFloor "70"
    }
    taxes {}
  }
  capabilities {
    name "Unternehmensberatung"
}}
```

Listing 1: USDL representation of consulting service

Several interesting USDL features map real-world situations to service description fragments. For example, the modelling of roles can map a restaurant, an associated delivery service and a training with the chef as services with corresponding opening or operating times. Compared to printed business registries, these structures already present an immense advantage when looking for a service to cover specific needs.

Yet, a number of weaknesses result from precisely this broad scope. Additional weaknesses were found in the realisation of certain XML language constructs and in the presentation within the Eclipse-based standalone USDL editor of version 0.5. A subset of ostensive weaknesses found by us will be briefly mentioned here, while a full report on the suitability of modelling particular real-world services in USDL can be found in an online report [Kur10].

- While industry-specific perspectives are planned, they are currently not part of the public specification. Therefore, modelling always exposes the entire structure which is often not desired, especially for services in the creativity domain like marketing or event management.

- Composite services in the real world can be extremely complex. For instance, a food delivery service may have separate product shopping cart and delivery options. USDL offers limited support for composite services.

- The pricing module of USDL is very powerful by allowing a great degree of granular price decomposition. However, this leads to diffcult price evaluation at runtime. A possible solution would be to add non-normative simple pricing information to each full specification, e.g., a service starting at 99 EUR. This enhancement would reflect imprecise price statements often seen in RWS advertisements.

- Availability as a temporal and spatial concept is not used to its full potential. This is a key metric to distinguish functionally identical or similar services and filter out services which are out of the question due to their unreachability.

- USDL service descriptions are likely used in user-friendly portals. However, USDL lacks unified graphical elements such as provider and service logos, banners and similar visual hints.

- The service-level module is very basic. It does not support ranges or dependency specifications between objectives. Legally valid contractual rights and obligations of RWS providers and consumers requires an expressive syntax if the aim is to replace currently used paper contracts with machine-readable documents.

- Legally required information such as tax numbers are not yet part of the language. For the completion of the Legal module, such real-world requirements need to be taken into account.

- The editor refuses to work properly with Unicode data and mandates to use XML encoding for non-ASCII characters, resulting in larger and harder to read documents.

We expect that the upcoming standardisation attempt will reduce the number and impact of the identified weaknesses and therefore increase the suitability of describing tradeable services in USDL.

3.2 Suitability of WSML

The Web Service Modelling Language (WSML) is a format for representing concepts from the corresponding service ontology WSMO [FRP+ 05]. Given that WSML is popular among existing SOA and semantic web service research and that several reasoners, registries and discovery components exist, we were interested to see if a new language like USDL was really necessary or if WSML could be used to model the relevant artefacts instead.

Compared to USDL, WSML is a rather computational low-level language which provides rich syntactical constructs for describing capabilities, mediators, properties and domains of services. The language is based on extended first-order logic and rule

language foundations such as terms, predicates and logical expressions [CPPT08]. WSML furthermore provides extensive annotation support which is very useful when processing descriptions at service marketplaces, as well as mappings to RDF and XML exchange syntaxes and to OWL ontologies. Similar to how OWL-S defines concepts specific to web services, the WSML semantics provide means to express web service ontologies, but could equally be used for RWS. Some language concepts like real-world effects specifications already extend the scope.

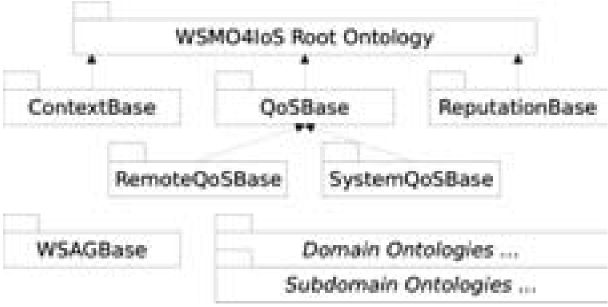

Figure 4: WSML base ontologies required for IoS platforms

While WSML is highly modular, a definition of modules is outside of the scope of the language. Therefore, concepts such as provider addresses and pricing information need to be captured in application-specific and site-specific WSML base ontologies as shown in figure 4. Additional functional domain ontologies like Consulting, Hotel booking or Translation, optionally divided into subdomains such as Book translation and Translation into Japanese, can be instantiated and the instances combined with instances of the non-functional properties and service concepts from the base ontologies to achieve rich descriptions and multiple discovery methods including multi-faceted browsing and goal or intent resolution.

The hypothetic base ontology set WSMO4IoS as designed in the figure has partially been realised by us to experiment with our findings. It contains definitions for non-functional properties such as local monitorable parameters (CPU load, memory consumption), remote monitorable parameters both on the service level (availability) and the invocation level (response time, success), and non-monitorable properties like a service's location, usage context and reputation. For the registration of RWS, machine-monitorable properties are of no concern. Especially with smaller companies, connecting real-world data sensors such as RfiD tags to software sensors used by IoS platform monitors seems to be not feasible, although technically possible for larger companies to automatically supervise properties such as shipping times. In contrast to this limitation, location and reputation information are highly important to the providers of RWS, especially due to the physically imposed geographic boundaries on some services. WSML provides syntax to describe post-conditions and effects which could translate to real-world effects. However, we decided to stay with the simple property syntax and

instantiate concepts from the ContextBase ontology. Optional base ontologies are included for further processing, e.g., WSAGBase to derive WS-Agreement SLA templates for contract-bound service usage. The listing 2 shows an excerpt from the WSML description of the consulting service.

```
instance providerMueller memberOf { wsag#Provider ,
wsag#ServiceInfo }
  wsag#providerName hasValue "Consulting Mueller Company"
  wsag#providerStreet hasValue "Dienstboulevard"
  wsag#providerCity hasValue "Dresden"
  wsag#providerPhone hasValue "+49 (351) 0000000"
  wsag#providerPersonName hasValue "Gustav Mueller"
  wsag#providerCertificates hasValue { isocert }
instance consultingservice memberOf { wsag#Service ,
wsag#ServiceInfo }
  wsag#serviceKey hasValue "Unternehmensberatung"
  wsag#serviceType hasValue wsag#HumanAtomic
instance isocert memberOf { reputation#Certificates ,
qos#ServiceSpec }
  qos#value hasValue "DIN ISO 9001"
  qos#unit hasValue ""
```

Listing 2: WSML representation of consulting service using WSMO4IoS

The nature of WSML supports modelling complex characteristics of a service without necessarily providing prior specification in schemas or base ontologies. For instance, in listing 3 a delivery service restricts its orders to EU countries and gives a rebate of 2% for recurring orders. Compared to USDL, the flexible syntax can be seen as advantage, however it also requires higher processing and reasoning resources.

```
capability
  sharedVariables ?customer
  precondition
    annotations
    dc#description "Only delivering to European Union."
    endAnnotations
    definedBy
      ?customer memberOf Customer
        and ?customer [hasResidence hasValue
ontomediator#eucountry].
  effect
    annotations
      dc#description "Any delivery turns customer into
patron."
    endAnnotations
    definedBy
      ?customer memberOf Customer and ?customer [isPatron
hasValue xsd#boolean("true")].

nfp
  RebatePrice hasValue ?price
  annotations
    dc#description "Patrons get a 2% rebate."
  endAnnotations
  definedBy
    ?customer[isPatron hasValue xsd#boolean("true")]
memberOf Customer
    implies ?price[hasAmount hasValue ?amount, hasCurrency
hasValue "EUR"] memberOf Price and numericMultiply(?amount,
0.98).
```

Listing 3: WSML representation of consulting service using WSMO4IoS

WSMO4IoS would have to be completed in order to draw a final conclusion about the suitability of the language. A major gap towards a description of RWS is the absence of a predefined pricing ontology. Hence, one could assume that in the Internet of Services, description syntax is less important than standardised and widely utilised base ontologies. Still, we assume that the computational power of WSML will be of great benefit over purely syntactical approaches when complex service bundles and compositions become commonplace, provided that service platforms can interpret the additional information. The language would be even more suitable if custom XML

Schema datatypes could be used from both web services and information systems relating to RWS.

As a next step, we intend to explore additional WSML modules and apply them to our samples. The conversion and sharing of base ontologies between various service description approaches could mean an interesting challenge. The ongoing work can be tracked at a dedicated website[2]. For further exploitation of WSML in the context of the IoS, we also recommend the creation of a global collaborative catalogue of base ontologies. The catalogue will help to reduce duplication and enable the integration with service discovery, service level agreement transformation and other runtime tasks, as well as design-time tools such as WSMO Studio.

3.3 Acceptance of IoS Concepts among Companies

Out of the 12 companies whose services we modelled, 5 indicated to us that they would like to immediately see the service descriptions being used on a public service marketplace independently from whether or not the companies would get direct access to modify the registry entries if needed. The remaining 7 were unsure. Therefore, we measured the acceptance of modelling and registration techniques in the IoS with 5 RWS providers. Acceptance is an important competitive metric which directly affects the quantity of turning potential into actual users [Kol01].

Service descriptions approved for public registration were registered into an instance of the ConQo semantic service registry [SBSB08]. Its service model mandates a domain-dependent WSML file with an arbitrary number of attached documents and hyperlinks, including USDL or WSDL files. For a preference-driven search and discovery over the service offering, USDL information would have to be transformed into WSML constructs to become visible to the ConQo reasoner. However, since search was not a goal of this study, we only considered few attributes such as service name, description and ownership specification. A service catalogue within a social network of users, communities and companies has been produced which reflects the contents of the service registry. The resulting service catalogue can be found online[3].

We perceived a general reluctance to specify prices and conditions upfront. Therefore, we suggest to include negotiation capabilities into the service description languages. Service providers would specify which input parameters affect the price on a mandatory or optional level. While SLA negotiation including QoS and pricing conditions is an established topic among SOA researchers, specifying negotiation metadata for a prior meta-negotiation about which properties are negotiable in which situation is a relatively new topic [BVMB08].

USDL in particular offers specification fields for employee roles and birth dates. The usage of these fields will depend on trading employee privacy and company protection versus customer needs and curiosity. If all service description fields are public, crawlers

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2 WSMO4IoS page: http://serviceplatform.org/wiki/WSMO4IoS
3 RWSDD service catalogue: http://crowdserving.com/real-world-services-in-dresden

could be created to exploit this information in non-intended ways. We expect this to become a major area of interest for privacy research along with the establishment and rising popularity of the IoS.

We also experienced that companies would need much easier-to-use guided tools and editors to bring their services in the IoS. Both the USDL editor and WSMO Studio are exclusively targeting technical users. Easy applications or web-based wizards could help to parallelise the collection of registration data from companies. The presence of a large number of service descriptions is one of the key success factors for service marketplaces due to the network effect [SV98].

Regarding the registration, our plan to let companies register the descriptions by themselves had to be put on hold despite the availability of a step-by-step documentation. We perceived both a problem of understanding the resulting declarative service descriptions and an incentive problem of what the benefits of registering the files would be. Therefore, we as marketplace operators performed the registration on behalf of the companies, which will obviously not scale. We recommend the standardisation of service package publishing interfaces and the inclusion of publishing functionality into modelling tools to streamline this process. We also suggest that service description ownership and dynamic content adaption (e.g., provider address updates) within service platforms be treated explicitly to convey the advantage of roaming between different hosters without losing information. Our discussion with the affected companies strengthened this view.

finally, the acceptance of post-registration processes like service usage and rating needs to be taken into account. While we don't cover these aspects in our current work, we intend to explore it later through complex service scenarios. For example, an RWS provider needs to offer a composed service which includes a web service interaction, and the web service shall be dynamically replaceable under the constraint that it won't ever cost more than a certain limited amount of money.

4 Related Work

This evaluation study is mainly related to different service description approaches and to surveys on the acceptance of service provisioning approaches on marketplaces.

Literature coverage of industry-driven electronic service description (e.g., WSDL, SAWSDL, WADL) and brokering (e.g., UDDI, ebXML) is quite complete. Surprisingly, while product taxonomies and declarative product descriptions also exist in standardised formats, only few publications focus on comprehensive machine-processable descriptions of business services to make them comparable, composable and tradeable

through marketplaces. An abstract meta-model to combine aspects from several approaches is given in [BF09]. Its authors further developed a concrete realisation as EMF meta-model with graphical representation and editor tooling. While USDL and WSMO4IoS are primarily subdivided into modules and base ontologies, both extensible with domain-specific concepts, the meta-model primarily considers the four service system dimensions component, resource, product and process. Both the meta-model and USDL have a fixed set of non-functional service properties, while WSMO-based description ontologies allow for dynamic sets of arbitrary properties. The resource model of the meta-model, which is not considered by USDL or WSMO4, is comparable to resource clauses in special web service and component description languages like CQML+. An apparent limitation of the meta-model approach and others is the lack of public syntax specifications and tools. Without these, service platform integration as well as suitability and acceptance studies cannot be performed.

Measuring the acceptance of service provisioning on marketplaces relates to similar work in the area of e-commerce. A dual perspective on buyers' and sellers' acceptance of trading good on marketplaces has been examined empirically in [Kol01]. Acceptance problems found by the study centre around a mismatch between supply and demand in certain configurations, for instance, consumers expecting better quality in one domain and more choice in another. Solving the mismatch requires thorough specification and processing of non-functional properties during matchmaking, which is provided by most advanced service description concepts. It also requires means to discover under-supply and subsequently techniques to describe and offer competitive offerings to close the gaps, which is outside the scope of service descriptions and needs to be provided by service platforms and marketplaces. The study omits service-specific arguments. Nevertheless, the findings resulting from the mismatch especially under the network effect equally apply to our work. Measuring a broad-scale acceptance of IoS service offering concepts will only become possible once IoS marketplaces will become more widely used in commercial environments.

On a minor scale, this study also relates to alternative combined handling of RWS and web services. Few approaches focus on a spectral view for describing and trading both conventional and electronic services as well as hybrid IT-supported conventional services. Related work on this aspect can be found in [CWV09].

5 Conclusions and Future Work

In the spectrum from fully electronic services to IT-independent business services, current Internet of Services approaches and platforms mostly concentrate on electronic or at least IT-supported services. However, we were able to demonstrate in the case study RWSDD that central service offering tasks such as modelling and registration of service descriptions have become more feasible and inclusive than with previous conventional SOA techniques. While the study criteria are only partially fulfilled, the expanded view on practical service trading helps to refine research results in the IoS.

Major barriers to wide adoption of the techniques can still be found in service description languages like USDL and WSML. They require a further evolution, especially in terms of standardised base vocabulary for expressing service properties, and improved user-friendly tooling for entering into an economy of scale by reaching a critical mass of self-empowered IoS participants.

Further crucial factors for durable acceptance of IoS ideas will be the availability of permanent service marketplace installations with guided service provisioning processes, the long-term manageability of service portfolios and the inclusion of user feedback into the service evolution. Future studies about RWS are expected to yield more concrete results about the post-registration usage phases. We expect such studies to be performed once the IoS infrastructures are completely developed and actively used.

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Essential Aspects of Compliance Management with Focus on Business Process Automation

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Abstract: Compliance requirements coming from laws, regulations and internal policies constrain how a company may carry out its business. A company must take various different actions for preventing compliance violations and for detecting them. Business processes have to be changed accordingly in order to adhere to these requirements. Manual controls need to be installed in order to affect the work which is done outside of IT systems. Technical controls are required for assuring compliance within IT systems. In this paper, we present a compliance management model that captures the compliance problem from a holistic point of view. We elaborate on a technical control which is called compliance fragment and we position it in the compliance management model. A compliance fragment is a connected, possibly incomplete process graph that can be used as a reusable building block for ensuring a consistent specification and integration of compliance into a workflow. In particular, we propose language extensions to BPEL for representing compliance fragments. Furthermore, we introduce a methodology for integrating compliance fragments into given workflows.

1 Introduction

The term compliance denotes all measures that need to be taken in order to adhere to requirements derived from laws, regulations, internal policies etc. As non-compliance may lead to tangible punishments, immediate reactions to these requirements become a necessary part of business process management. Many of these requirements necessitate performing profound changes of the business processes and their technical implementations, referred to as workflows [LR00]. These changes have to be verifiable, traceable, and checkable for supporting governance and for providing evidence of compliance in case of an audit. Consequently, a company is compliant when it can proof that all requirements have been implemented and fulfilled in an appropriate manner. This includes that the requirements are accordingly monitored and adequately checked. Therefore, we need concepts for consistent representation of compliance requirements and methods for their reliable integration into business processes and workflows respectively.

In this paper, we build on and extend recent works related to compliance management in business processes. In [Da09] we described the research challenges for governing compliance in service-oriented architectures, spanning from design to execution and evaluation of concerns. As one part of an overall solution, we focus on workflows that have to be made compliant. In [Sc10a] we proposed to use process fragments as compliance controls and we have specified and described a life cycle for their usage. We discussed two main usage scenarios for the application of these *compliance fragments*. The first scenario is to use them during process design as reusable building blocks. They can either be glued into an existing process, or they can be used to completely build up a process from scratch. The second scenario is to annotate compliance fragments to a process in order to constrain the behavior of the process during its execution. We also investigate how to manage compliance in Software as a Service (SaaS) scenarios. In [Sc09] we introduced the concept of process templates that implicitly contain compliance controls as well as points of variability for customization. Furthermore, we presented an algorithm which ensures that these constraints are not violated. In this paper, we focus on the design time aspects of compliant workflow design. Aside from the compliance management model which we discuss in Section 3, the main contributions of this work comprise a way to represent reusable compliance controls for workflows, and a mechanism to integrate them into a given workflow.

This paper is structured as follows: the background of our approach and related work is discussed in Section 2. In Section 3 we present a general compliance management model and position the concept of compliance fragments in it. In Section 4 we specify language extensions to the Business Process Execution Language (BPEL) [Oa07] for representing compliance fragments. We also specify a methodology for integrating compliance fragments into a workflow. Finally, conclusions are provided in Section 5.

2 Background and Related Work

In the following we provide some background information on the usage of compliance fragments in process design. First of all, before a compliance fragment can be used it needs to be created. In [Sc10a] we described two manual ways. One way is that a domain expert analyzes existing processes and extracts meaningful structures, i.e., activities and control dependency among them. The other way is to design a fragment from scratch based on a specification of requirements. In order to utilize fragments for compliance both ways are applicable. The investigation of automatic techniques for identification and extraction of compliance fragments from existing processes is ongoing research in the COMPAS[1] project. However, independent of how the fragment has been created, it is important to have a proof that the process fragment is really implementing particular compliance requirements. To provide this proof, the compliance requirements need to be formalized in a language that can be understood by tools for verification and model checking. For instance, linear temporal logic (LTL) allows designers to encode requirements about the execution path in logical formulae.

[1] COMPAS: Compliance-driven Models, Languages, and Architectures for Services, www.compas-ict.eu.

Such formal rules can be used in model checkers to verify if the requirements are satisfied in a process [KA09]. The formalization of compliance requirements and their checking against a process or against a single compliance fragment is an important step for workflow compliance as we discuss in [Sc10b], but this is not the focus of this paper.

There exist different concepts for mapping compliance requirements to technical controls that can be installed in a workflow. One possibility for integrating additional steps related to compliance is the usage of sub processes or similar concepts such as Worklets [Ad05]. In this way modular requirements can be implemented, for example the retrieval and validation of a trusted timestamp from a certified timestamp provider can be defined as a sub process. Beside sub processes, there are other concepts that can be used to make a workflow compliant. Business processes can be annotated with constraints which have to be checked during design time or runtime in order to prevent violation of compliance rules. A variable can for example be annotated with a constraint allowing numbers between one and ten to be assigned. The case-handling approach [VA97] allows the ad-hoc definition of processes that adhere to certain rules like: "Activity A must be executed at least once until the process is terminated." In addition, approaches that address the detection of compliance violations in a process are currently discussed [Go09]. The concept of compliance fragments we present in this paper takes advantage of the concepts listed above and combines their strengths to ensure compliant behavior of a workflow.

3 Compliance Management in Business Processes

In this section, we propose a general model for compliance management (see Figure 1). In particular we describe the various actions a company can take in order to establish a strategy for achieving overall compliance. The compliance management model gives an overview of the different kinds of technical and manual controls. We elaborate on compliance fragments that can be installed as technical controls in workflow-based applications.

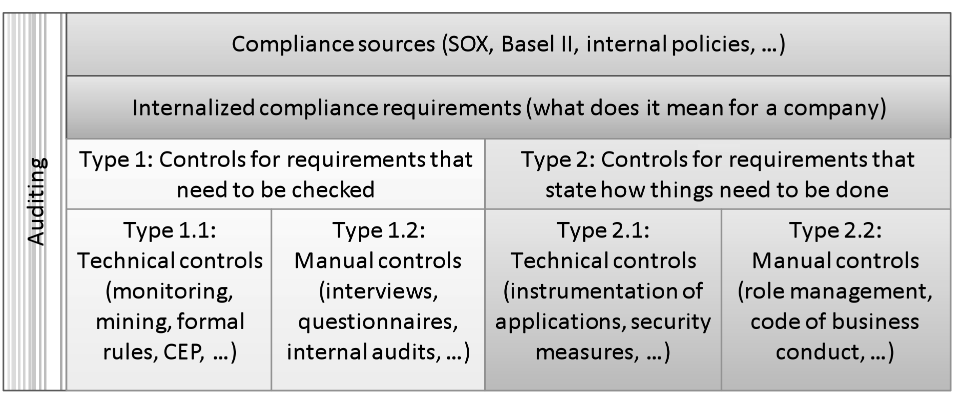


Figure 1: Compliance management model

3.1 Compliance Management Model

An initial step of compliance management in a company is to perform a compliance assessment. In this step business experts (e.g., lawyers, consultants) collect all relevant *compliance sources* (e.g., laws, regulations, internal policies). The sources are then interpreted by these experts in order to define compliance requirements for the company and its business processes, i.e., *internalized* [Da09]. Compliance requirements basically involve any aspect of the processes in a company: requirements are related to control flow, information usage, location (of an actor in a process, data or resources), security, quality of service, monitoring, privacy, trust, and licensing [HPO08]. As compliance sources possibly give leeway in the interpretation, it is unlikely that two companies have exactly the same set of compliance requirements, or the same implementation thereof. Some requirements are generally like "use appropriate encryption methods". How such a requirement will be treated, depends on the particular interpretation of the compliance experts and on the technical infrastructure that is available in a company. In addition, as the degree of automation of the business processes differs from company to company, the choice of *controls* also differs. We distinguish between technical controls which are the measures that can be taken within IT systems, and manual controls which are measures that can be taken outside IT systems.

Type 1: Controls for requirements that need to be checked.

Type 1.1. Controls of type 1.1 provide functionality for compliance checking within IT systems. Controls of this type include checking of constraints during design time, at runtime, or offline (i.e., after-the-fact). Depending on the particular application that has to be checked, constraints can be specified in machine-readable languages like logical languages (LTL, CTL, Deontic Logic etc.), in domain-specific languages or in graph-based languages like annotation fragments as we proposed in [Sc10a]. Appropriate software components need to be installed for checking these constraints, for instance a model checker is required for checking logical constraints at design time and complex event processing (CEP) engines are often used for runtime checking. Additionally, offline monitoring is useful in many scenarios (e.g., process analysis, process mining). Controls of this type in general do not change the behavior of the IT system, but they have the prerequisite that the information which is required for checking is available. For this reason some changes of the involved systems might be necessary, in order to make the required information available. For instance, keeping records of electronic communication is crucial for providing later evidence of compliance. This might require modifications of the involved systems to support the extraction, collection, and storage of sent and received emails, committed transactions, and other data (e.g., program execution events or audit trails).

Type 1.2. Controls of type 1.2 refer to manual checking of compliance. The usage of this kind of controls is necessary when the requirement cannot be checked within an IT system in a (semi-) automated fashion. For instance, interviews and questionnaires can be used for checking processes within a company which are not automated. Recently, anonymous complaint boxes (e.g., for customers) and so-called "Whistleblowing hotlines" are also attracting interest of companies for achieving compliance.

Several forms of audits represent a supplementary control. Audits include sample checks performed for instance by a compliance officer, a technical audit of a software framework, a financial audit, or an audit with a particular subject like “customer data protection”. In addition to that, certification of a software system according to particular requirements can also be a workable measure.

Type 2: Controls for requirements that state how things need to be done.

Type 2.1. Controls of type 2.1 have an impact on the behavior of an IT system. Many compliance requirements refer to security, privacy or trust. Thus, hardening the software environment is a basic control. This includes installation and proper configuration of rights and role management (like access control lists), firewalls, anti-virus, browser security, license management etc. Custom settings of the applications and their data storage may also be necessary, e.g., configuring a database to store particular data in an encrypted manner, or installing a trigger that customer data may only be deleted after ten years. Some applications can be configured with annotations or with a deployment descriptor to use particular settings, e.g., related to security. As applications can invoke services provided by a business partner, a company must ensure that the applied service also adheres to the internalized requirements. Policies and Service Level Agreements (SLA) are used for this purpose. In our research, we focus on the process structures that allow an augmentation of the technical implementation of a business process with activities related to compliance.

Type 2.2. Controls of type 2.2 are the measures outside of IT systems. More and more companies are performing organizational changes for compliance management, e.g., the Siemens AG dramatically increased the number of employees involved in compliance programs [Si08]. This includes for instance the installation of one or more compliance officers and role management for preventing violations of segregation of duty or binding of duty requirements. Employees are instructed to adhere to the compliance requirements with particular guidelines or a “code of business conduct”. Management of the security of the company’s facility is also important. Analogous to workflows, business processes can be inter-organizational as well (e.g., involve subcontractors). Therefore, a company must ensure that its business partners also follow particular requirements. According contracts are required for this. A necessary action for enabling compliance checking and for supporting an audit is to keep records of documents, e.g., in tax consultancy most documents typically have to be stored for at least ten years. Keeping records of talks is also important, e.g., the minutes from a product advice talk in a bank are required for providing proof that the risks of a product have been properly explained.

Controls of different types can be combined to more advanced instruments [An09]. For example, software components of type 1.1 for checking for compliance violations can be combined with instruments of type 2.1 for dynamically changing the behavior of a running system (so-called compliance enforcement). Finally, for companies it is desirable to have a way to flexibly react on changes of requirements, for instance when a law is changed. Therefore, a connection of the compliance sources, the internalized requirements and the controls which are used to implement them, needs to be documented and maintained. This is also important to provide transparency to an auditor.

3.2 Compliance Fragments

A fundamental insight in our research is that compliance requirements related to workflows do not necessarily require new types of activities or completely new language constructs. The compliance requirements on which we base this work are provided by case studies which are defined by industry partners of the COMPAS research project: Thales Services SAS (France) and Telcordia Poland, in cooperation with PriceWaterhouseCoopers Accountants N.V. (the Netherlands). These requirements are mainly related to checking (*Type 1.1*) and enabling (*Type 2.1*) of security, role management, traceability, audit trails, quality of service, and licensing. Most of the security requirements related to workflows can be realized with available security frameworks. Role management in a workflow based on BPEL can be implemented with BPEL4People [Kl07] or using annotations and according tools for checking. Traceability requires the extension of a workflow engine in order to emit execution events that are augmented with unique identifiers, as our project partners showed in [Ho10]. However, what is missing for achieving compliance in service-based applications is a concept for reusable process structures that allows a consistent management of compliance requirements within workflows (*Type 2.1*, with focus on business process automation).

To illustrate our approach, we take a simplified loan approval process as an example. The activity labeled "Approval by Manager" is the step where a manger can approve a loan request (see Figure 2, left). We assume a changed internal policy, stating that a loan request can be approved without involving a manager if the risk is low. Whether a risk is high or low can be decided by a clerk. To implement this requirement, the process has to be adjusted. By reusing a compliance fragment for decisions (which someone created before) we can add the functionality to check a loan request a second time (see the center part of Figure 2). The right part of Figure 2 shows the process that is augmented with the new compliance fragment (light grey).

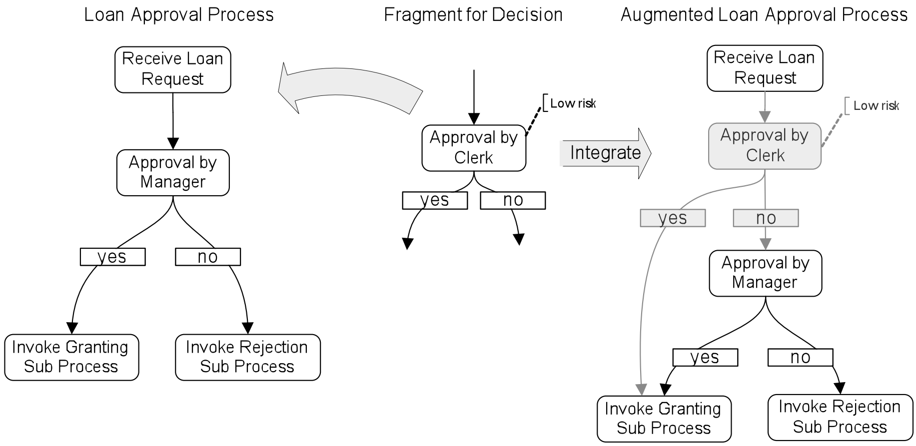


Figure 2: A loan approval process is being augmented with a compliance fragment for an additional decision

In [Sc10a] we introduced a compliance fragment as a connected, possibly incomplete process graph that can be used as a reusable building block to realize compliance requirements in terms of process logic. Compliance fragments can be used to augment a process to make it compliant to requirements related to control structures and activities to be executed. Compared to a normal process, a compliance fragment has significantly relaxed completeness and consistency criteria. For instance, a process graph has to contain a process start and a process end node for consistency. A fragment may contain such nodes, but it is not required to. In addition, a fragment may also contain activity placeholders (so-called regions) that can be filled with activities or other fragments. The concept of compliance fragments we proposed in [Sc10a] allows us to specify various different kinds of fragments. An important differentiation is how many entries and exits a fragment has. A fragment with no entries has the meaning of a process start fragment, which is useful for modelling a process from scratch. However, when using more than one of such a fragment, a conflict might occur due to multiple start nodes. The fragments we focus on have at least one entry and one exit.

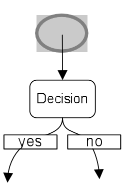
4 Managing Compliance Fragments

In this section, we propose extensions to BPEL to provide the capability to represent and serialize compliance fragments (Section 4.1). Subsequently, we present a methodology for integrating compliance fragments into a given workflow (Section 4.2).

4.1 BPEL Extensions for Compliance Fragments

We propose design time extensions to BPEL which do not require an extension of the runtime environment that executes the processes. All extensions except the extension for unique identifiers are replaced during integration of the fragment into the process (discussed in Section 4.2). We use the attribute `mustUnderstand="yes"` for the extension namespace so that a process engine will reject running a process in which not all placeholders have been replaced by standard BPEL constructs.

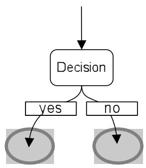
frg:fragmentEntry. The entry of a fragment is a placeholder for integration into a given process or for composition of multiple fragments. A `fragmentEntry` hast to have one or more leaving control links, and it must not have any incoming control links. An attribute (`type="mandatory|optional"`) specifies whether the entry has to be wired for assuring compliant behavior, or if it can be neglected and removed. Figure 3 illustrates the concept and the schema of the `fragmentEntry`.




```
<frg:fragmentEntry name="entryName" type="mandatory|optional">
   <bpws:sources>
      <bpws:source linkName="linkName" />+
   </bpws:sources>
</frg:fragmentEntry>
```

Figure 3: BPEL extension for fragment entry

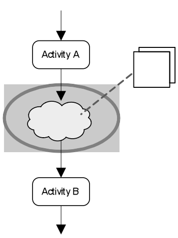
frg:fragmentExit. Analogously to an entry, a `fragmentExit` is a placeholder for a composition. It must have at least one incoming control link, and it must not have any leaving control links. A `fragmentExit` has the same attribute (`type`) as a `fragmentEntry` with analogous semantics. If a `fragmentEntry` has multiple incoming control links, then all of those control links have to have their target in one and the same activity in the final composition. Figure 4 illustrates the `fragmentExit` and its schema in BPEL.




```
<frg:fragmentExit name="exitName" type="mandatory|optional">
   <bpws:targets>
      <bpws:target linkName="linkName"/>+
   </bpws:targets>
</frg:fragmentExit>
```

Figure 4: BPEL extension for fragment exit

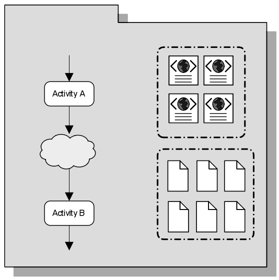
frg:fragmentRegion. A `fragmentRegion` is a placeholder that needs to be replaced with other BPEL structures. A region can be filled with standard activities, but it can also be used for composition of process fragments. Constraints can be imposed on a region for specifying how it may be filled. By using an annotation mechanism the constraints can be specified in an arbitrary format in a separate document. Figure 5 (left) shows a `fragmentRegion` (the cloud shape) on which constraints are imposed (the documents shape). We do not specify which language(s) to use for stating the constraints at this point in order to keep the overall concept modular and composable. Figure 5 (right) shows the schema for a fragment region.




```
<frg:fragmentRegion name="regionName">
   <bpws:targets>
      <bpws:target linkName="linkName"/>+
   </bpws:targets>
   <bpws:sources>
      <bpws:source linkName="linkName"/>+
   </bpws:sources>
</frg:fragmentRegion>
```

Figure 5: BPEL extension for fragment region

frg:fragmentScope. A process fragment may define a context (e.g., variables, data types). In BPEL, the `scope` construct is used for this purpose. However, we have to distinguish between the scope of a fragment and a BPEL `scope` to avoid confusion on the one hand, and to provide clear semantics on the other hand. A `fragmentScope` which is derived from the BPEL `scope` can be used as container for context constructs, such as `variables`, `partnerLinks`, `faultHandlers` etc. A `fragmentScope` has the same characteristics as a BPEL `scope` in terms of XML schema (see Figure 6).

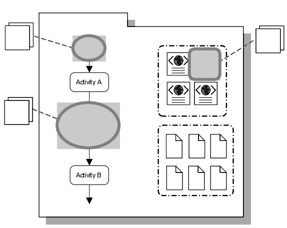



```
<bpws:extensionActivity>
   <frg:fragmentScope name="fragmentScopeName">
      <bpws:variables>
        <bpws:variable .../>+
      </bpws:variables>
      <!— Other context -->
      <frg:fragmentFlow name="fragmentFlowName">
        <bpws:links>
          <bpws:link name="linkName" />*
        </bpws:links>
        <frg:fragmentEntry ...
```

Figure 6: BPEL extension for fragment container

frg:fragmentFlow. BPEL is a hybrid language, both graph-based and block-structured [Ko09]. To support the concept of multiple entries and exits of a fragment we take the graph-based part, i.e., the BPEL `flow` construct as basis. Just like a `fragmentScope` is not the same as a BPEL `scope`, a `fragmentFlow` is not the same as a standard BPEL `flow`. When integrating the fragment into a process, the control links which are nested in the `fragmentFlow` have to be merged with the control links which are nested in the ancestor BPEL `flow`. Figure 6 shows how a `fragmentScope` and a `fragmentFlow` can be used for providing a container for a compliance fragment.

ext:id. In order to reference constructs from the outside, they must have a unique identifier. Using the name of a construct as identifier causes problems as the name might be changed often; this requires all references to be updated accordingly. Thus, we prefer a universally unique identifier (UUID) [LMS05] for this purpose. In order to keep the fragment clean from the constraints, we propose to extend all BPEL elements with an identifier attribute. An annotation mechanism which references this identifier allows the specification of constraints on regions and other BPEL constructs (e.g., impose constraints on variables) from the outside. For the identifier extension (see Figure 7) we have chosen a different namespace (with prefix `ext`) than for the other extensions as this extension can be ignored by an execution engine, i.e., `mustUnderstand="no"`.




```
<!-- for constrained entries -->
<frg:fragmentEntry name="entryName" ext:id="unique" />

<!-- for constrained regions -->
<frg:fragmentRegion name="regionName" ext:id="unique" />

<!—for constrained variables -->
<bpws:variable name="variableName" ext:id="unique" />
```

Figure 7: BPEL extension for unique identifiers

Using identifiers is also important for traceability and for maintenance reasons. Traceability in an execution environment can be supported by augmenting execution events with identifiers of the activities that are executed during runtime. The identifiers also allow distinguishing between the original parts of the process and integrated compliance fragments. The XML schema of the extensions and a concrete compliance fragment using these extensions can be found in COMPAS deliverable [Eu10].

4.2 Integrating Compliance Fragments into Workflows

During integration entries and exits of a fragment have to be “wired” with the process, i.e., control links between process activities and fragment activities are being established to obtain a complete and executable process. Placeholders are replaced with real functionality, i.e., the parameters are replaced with specific values, and regions are filled with activities or other fragments. In the following, we elaborate the different steps that have to be accomplished in order to incorporate a compliance fragment into an existing process. As illustrated in Figure 8, we use the concept of plugs to graphically represent a `fragmentEntry` and a `fragmentExit`. In order to wire a `fragmentEntry` (see Figure 8) we have to find and select a possible `fragmentExit` which can be plugged into it.

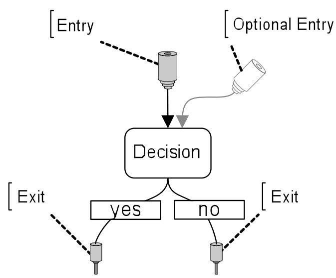


Figure 8: Compliance fragment for decisions where entries and exits are shown as plugs

If a former integration operation has not yet been completed, the available entries or exits can be chosen. Otherwise, either a new control link has to be created or an existing link has to be unplugged (i.e., broken) into a `fragmentExit` and a `fragmentEntry` as illustrated in Figure 9. Optional entries of a fragment are not required in any case. They can either be wired with the above described operations, or be removed. They are not required for the realization of the compliance feature that the fragment implements, but can be useful in process modeling. For instance, they can be used to define an additional control dependency to synchronize parallel paths. Wiring the exits of a fragment is done in an analogous manner. To wire an exit with an entry these constructs need to be plugged together: Transition conditions that possibly exist either need to be merged (using logical and) or one of them needs to be selected. Plugged connectors are transformed into one control link, i.e., a new link is inserted from the `source` of the `fragmentExit` to the `target` of the `fragmentEntry`. The helper constructs for the entry and the exit connectors are then no longer needed and can be removed.

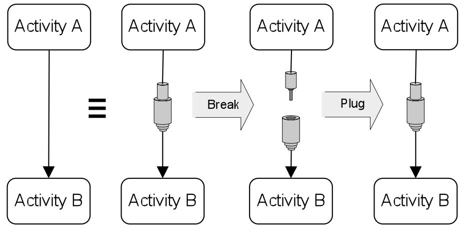


Figure 9: Breaking a control link and plugging an exit into an entry

The context defined in the `fragmentScope` (e.g., `variables`) has to be merged with the process context in order to complete the procedure of integration of a fragment into a process. Corresponding artifacts like variables can be matched based on their name, identifier, type or other attributes. Possibly, data types used in the fragment have to be adjusted to those used in the process for compatibility (e.g., Integer vs. Long). If any fault, compensation and termination handling is defined in the `fragmentScope`, this also needs to be taken into account. The main challenge when implementing design tool support for integration is how to design an easy-to-use wizard that assists the user in the wiring and in merging of the contexts. The integration is complete when all mandatory entries and exits have been wired, all optional ones are either wired or removed, all regions are filled or removed, and the context of the fragment and the process have been merged. In addition, the WSDL interface descriptions and policies which might be attached to a compliance fragment need to be combined with the WSDL and the policies of the process. After integration the process does not contain any fragment-related language extensions anymore, except for the identifiers used on the fragment constructs.

5 Conclusion and Future Work

In this paper, we have presented the essential aspects of compliance management in general and elaborated a workflow-based approach as one part of an overall solution for achieving compliance. We have discussed concrete language extensions to the process execution language BPEL for enabling compliant service composition with compliance fragments. Additionally, we have discussed a mechanism to integrate compliance fragments into workflows. With the concept of compliance fragments we can address requirements that concern the activities *within a workflow*, i.e., concerning the service invocations and human tasks defined therein, as well as their control dependency. The impact of compliance is however not limited to the workflow as we showed in the compliance management model. It also has an effect on the various applications and humans which are involved in the business processes. For instance, constraints on data storage fall into the category of requirements that can be tackled with technical controls, but not with the aid of compliance fragments. Further technical and non-technical concepts are needed for an overall approach to compliant business process automation and a compliant business.

Managing change of compliance requirements is another challenge that needs to be addressed. What is the methodology for updating a business process that has already been augmented with compliance fragments? As a first step to answer this question we investigate further techniques for managing compliance fragments (extraction, highlighting, and hiding). Furthermore, we examine the usage of different languages for stating constraints on the placeholders in a fragment, i.e., on the regions. Especially aggregation and combination of constraints in compositions is a challenge. Besides this, we are developing tools for compliance template and compliance fragment management.

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Ad-hoc Management Capabilities for Distributed Business Processes*

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Abstract: Advanced business processes are mostly distributed and require highly flexible management capabilities. In such scenarios, process parts often leave their initiator's direct sphere of influence – while management requires both *monitoring* as well as *instant reaction capabilities* anytime during the overall execution of the process. However, realizing such functions is often difficult, e.g. due to the heterogeneity and temporal disconnectivity of participating execution systems. Therefore, this contribution proposes a two-tier concept for monitoring and controlling distributed processes by representing a process management system as a *manageable resource* according to the WSDM standard. Based on a minimal shared model of management capabilities it allows to define customized events and processing rules for influencing business processes executed on a remote (and even on a temporarily disconnected) process management system. Applicability is demonstrated by a scenario-based evaluation on distributed WS-BPEL and XPDL processes.

1 Motivation

Today's competitive business collaborations highly benefit from transparency and visibility of the status of their business process networks. Within a single organization, *business activity monitoring (BAM)* technologies support real-time analytics about running business transactions and allow for the correlation of events for causalities, aggregates, thresholds, and alerts based on user-defined preferences. The analyzed information is delivered in (near) real time and provides an important basis to detect failures and non-compliances, to react to them accordingly and in sufficient time and, thus, to optimize the execution of processes in whole or in part.

However, to stay competitive and provide new value-added products and services, often also *cross-organizational collaborations* become necessary which span business processes between several organizations and different process management systems. Here, not only atomic resources such as employees, machines and services, but also the execution of a process instance itself can be distributed. Figure 1 shows examples for

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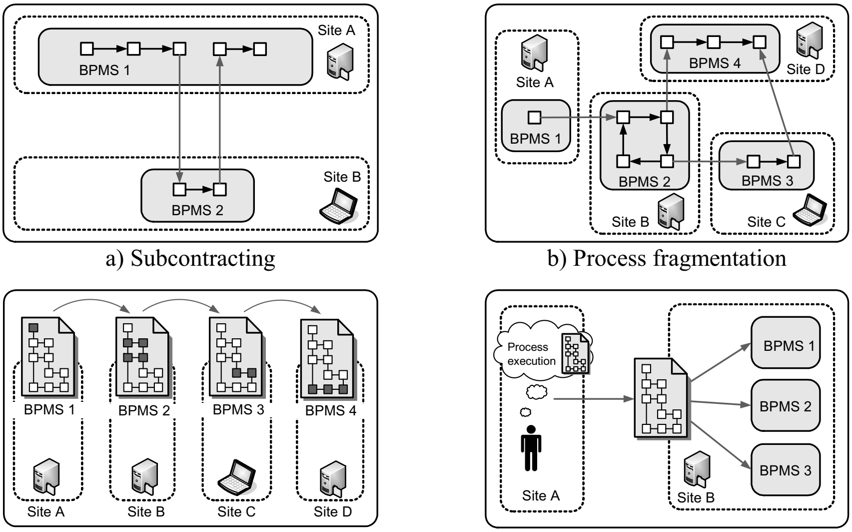


a) Subcontracting b) Process fragmentation

c) Process instance migration d) BPM-as-a-Service

Figure 1: Examples for the distribution of process execution [vdA00,ZK+10]

such distribution, realized as *subcontracting* of single process parts, *fragmentation* of processes, *process instance migration* from one workplace to another, and *BPM-as-a-Service* where the execution of a business process is fully operated by an external provider [vdA00, ZK+10]. Considering resulting *cross-organizational processes*, it is even more relevant to gather information about the execution on the remote system, because such participants may be dynamically selected or exchanged on the basis of their workload, context or QoS parameters. Cross-organizational monitoring and controlling capabilities are thus important to support the controllability of active process parts and – based on the collected information and experiences – optimize the distribution and execution of upcoming processes.

As a current drawback, today's BPM systems mostly consider monitoring and controlling of single centralized process executions, are often heterogeneous and do not provide standardized runtime monitoring or management APIs [vL+08]. Therefore, an integration of runtime monitoring information from different source systems is hardly possible yet. Required possibilities to also take influence on a remote process execution and to react to the observed behavior of the process (preferably in real time) are still challenging. This paper therefore aims at a concept and supporting infrastructure to flexibly collect information about the execution of process parts running on a remote system, to automatically process this information and to predefine and execute timely reactions to detected complex situations where ever necessary. Therefore, the rest of this paper is organized as follows: Section 2 motivates the need for a cross-organizational management approach for distributed business processes based on existing and related work. Section 3 presents a two-tier middleware extension for process management systems in order to support the provision and utilization of ad-hoc management capabilities. Section 4 analyzes applicability of the proposed concepts and Section 5 concludes the paper.

2 Background and Related Work

Research in the area of monitoring constitutes an important part of the management of distributed processes. Relevant previous approaches use the idea of extending existing process models by weaving in additional activities which call-back to a central monitoring system (e.g. [BGG04, BG05]). Thereby, the user initiating the process can build up his own monitoring system according to his individual preferences, e.g. accessing the status of the process instances, the duration of activities or the actual navigation of control flow. Neither agreements nor the adaptation of the partner system are required. Nevertheless, many information interesting for distribution, such as current system properties (e.g. the location where the process is executed, or the current workload of the engine), the number and type of deployed (but uninitiated) process models or the occurrence of internal process instance events (e.g. errors) are not visible. Furthermore, inserting additional activities after each functional task may result in a huge monitoring overhead – in the worst case expanding the original process description up to its double size, potentially decreasing execution performance considerably and mixing business logic and technical management logic in an undesired way [MWL08]. If the monitoring system becomes unavailable, the execution of the functional process is delayed or is likely to fail. Furthermore, appropriate actions depending on the results of the gathered information are limited, because running process activities cannot be influenced, e.g. cancelled, as the remote system does not provide an interface for such operations.

In order to preserve efficiency of process execution while at the same time allow quick and adequate reactions to predefined situations, the subscription to *process-related events* and their corresponding processing are attached a high importance [vA09]. While a *primitive event* simply represents some relevant change of a certain property (e.g. change of a process's status, a workload shift, etc.) *complex events* represent some arbitrarily complex inference of information from one or more primitive or other complex events [Luc02]. This is achieved by so called *Complex Event Processing (CEP)* and *Event Stream Processing* techniques. As an example, the ESPER project[1] addresses business process management and automation, i.e. process monitoring, BAM, reporting exceptions and operational intelligence. It uses an SQL-based query language to express rules and provides a rule engine for complex event processing. In order to address the heterogeneity of possible event sources, common agreements and standards for the representation of events (e.g. IBM's *Common Base Event*) as well as for the specification of complex event inference statements are required. The specification of reactions to (complex) events is equally important. Rule-based approaches, especially *Event-Condition-Action* rules, are widely used but due to manifold application domains neither the event, nor the condition or action representations are commonly agreed on. Wetzstein et al. [WK+10] therefore present an approach to support monitoring in service choreographies based on agreements about events to be shared with other partners and using complex event processing to derive key performance indicators for the overall process execution. However, this approach still only focuses on the subscription to events, but neither offers the possibility for requesting monitoring information on demand nor for initiating ad-hoc management actions.

[1] http://esper.codehaus.org/

As a foundation for the interoperability of heterogeneous workflow management systems, the Workflow Management Coalition (WfMC) has issued the *Workflow Reference Model* which also contains administration and monitoring tools for the management of users, resources and processes [WfM98]. An overview of management operations is proposed here, especially for user and role management (e.g. changing privileges of users), audit management (e.g. querying logs and audit trails), resource control (e.g. concurrency levels, thresholds), process supervisory functions (e.g. termination of process instances) and process status functions (e.g. fetching information about process instances). Associated specifications for achieving workflow interoperability (e.g. Wf-XML [SPG04]) are more detailed, but still focus on sending, installing and retrieving process definitions to/from a remote process engine. However, the idea of exchanging process management related information based on a common model by using standard web services is very interesting. The *Web Services Distributed Management (WSDM)* standard develops this idea a bit further. It allows specifying an arbitrary resource (e.g. a printer) as a so-called *manageable resource* which offers a set of resource-dependent properties accessible by a self describing service interface [OAS06b]. Providing such resource properties requires specifying a model as a mutual understanding of the resource to be managed. However, only a model supporting the *management of web services (MOWS)* [OAS06a] themselves has been developed. The first part of the work presented here therefore proposes a model to exchange basic information and control options for business process management systems involved in cross-organizational collaborations. A similar basis has been proposed by van Lessen et al. [vL+08] for WS-BPEL process instances. In this paper, however, we are extending this idea by also including relevant process model and process engine properties as well as related events, and, as the second part of this work, presenting a loosely coupled management component in order to analyze and process the received information either on-site or remotely.

3 A Two-Tier Process Management Middleware

The approach presented here proposes a *service-based common management interface* and uses *complex event processing* in order to specify user-defined management rules and actions. Therefore, a business process management system is considered as a *manageable resource* according to the understanding of WSDM. Defining the elements and properties of this manageable resource, relevant functionalities such as data retrieval, event subscription and control options are exposed as services and can be integrated in a standard registry and thus in existing and future applications. Based on that, an additional component uses the resulting management services and events in order to specify user-defined monitoring and management (re-)actions.

3.1 Tier 1: Process Management System as a Manageable Resource

In order to find an adequate basis for a common understanding of the elements and attributes relevant for distributed process management, an analysis of several current practical and theoretical approaches and systems as well as abstract models and concrete products for traditional and distributed business process management has been carried

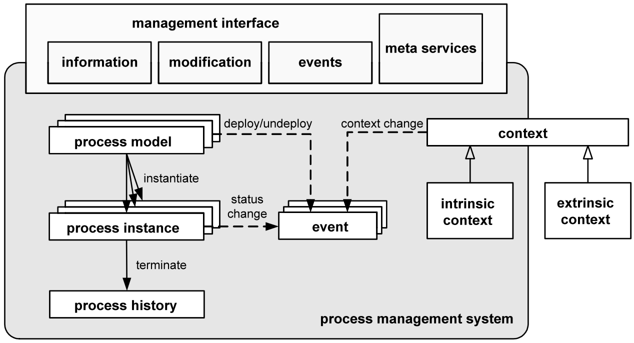


Figure 2: Process management system as manageable resource

out. The analysis has lead to the identification of most relevant management entities and a resulting basic model which is shown in Figure 2. It holds the process management system as a manageable resource which can be accessed by a service-based management interface either by pulling read-only information about its entities (*information interface*), by asking for manipulation of entity values (*modification interface*) or for receiving events emitted by the entities (*event interface*). To provide information about the management itself, a *meta interface* allows to access information about capabilities and operations for the configuration of the three aforementioned interfaces.

In the context of distributed process management, the proposed entities of a process management system include the *process models* which are deployed to the process engine, the *process instances* which are instantiations of these models (representing the processes which are currently running), and the *process histories* which contain information about processes which have already been finished (cp. Figure 2). Furthermore, to consider the special characteristics of distributed process management (such as mobility, cooperation and dynamic assignment) the process management system has a relevant *context* comprised of the *intrinsic context* of the process engine (e.g. system properties such as workload or service availability), and the *extrinsic context* (e.g. location or weather). Both types of context can either be static (e.g. the identity of the system's owner) or dynamic (e.g. the current workload). Generic context models which can be customized for such application are e.g. proposed by [KZTL08].

Figures 3 and 4 show refinements of the entities *process model* and *process instance* as manageable resources. Here, a process consists of *activities* which are connected by *transitions* to define a control flow (potentially restricted by a *condition*), and a set of *data fields* using a certain *data type* also defined within the process model. Furthermore, participants can be predefined as required *performers* for specific activities which are especially important in the context of distributed process management as this element contributes to the selection of partner systems. A process instance (cp. Figure 4) extends its process model by implementing the associated runtime information. Most importantly, this involves the *status of the running process* (e.g. executing, suspended, in error), the specific *values of the data fields*, the *status of the activities* (e.g. running, skipped), the *evaluation* of transition conditions (true/false) and the *actual performers* who are finally executing the activities. Finally, *process histories* reflect the entities of

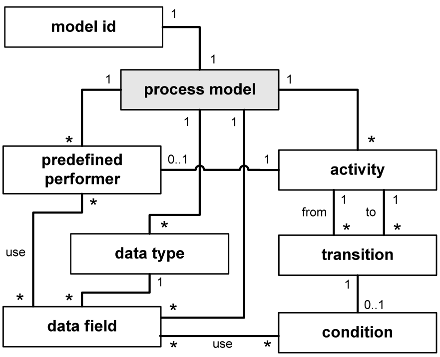


Figure 3: Process model as manageable resource

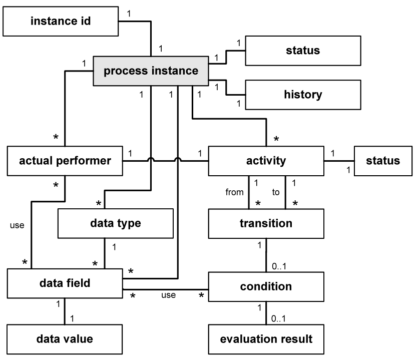


Figure 4: Process instance as manageable resource

the terminated process instances in a static way (not depicted). In order to enable a distributed execution and a respective management, all three entities need to have a unique identifier for the correlation of requests.

According to existing approaches such as Wf-XML [SPG04], all entities contain a number of sub entities and individual atomic properties, e.g. a process engine has a current workload expressed as the number of running process instances and CPU load, or a process instance activity has a start time, a duration and an end time. Creation of entity instances and changes of their properties' values are effecting the associated *events*. In order to allow manageability, exchanging information about a resource property requires a uniform and unambiguous representation and interpretation of values, e.g. represented as standard or complex data types, and a metric. Furthermore, the *modifiability* (e.g. read or read-write), the *availability* of the property (e.g. before, during or after execution of the process or the activity) and the *mutability* and *frequency of updates* should be specified. Due to space limitations and similarity to existing meta models, the enumeration of relevant entity properties and events should, however, not be part of this paper.

3.2 Tier 2: Management Component for Complex Event Processing

Providing informational and manipulative services and the possibility to subscribe to events based on a common understanding such as established in Section 3.1, arbitrary management applications can be composed in order to collect information and react to even complex situations in a user-defined way. The general methodology to support such operations is based on a loosely-coupled management component which is depicted in Figure 5: The user who is initiating a controlled distributed execution of a process (in the following called the *customer*) takes the original process description to be executed and creates an additional document (*management document*) which holds the customer's requirements for the management of this process (*management rules*). Here, the term *management* subsumes all objects, situations and operations which are, from the customer's perspective, relevant for the correct execution and administration of the distributed process and are not covered by the functional business process description. Relevant objects are the entities of the model presented in Section 3.1, e.g. process models, instances and data objects. Situations and operations are described within the manage-

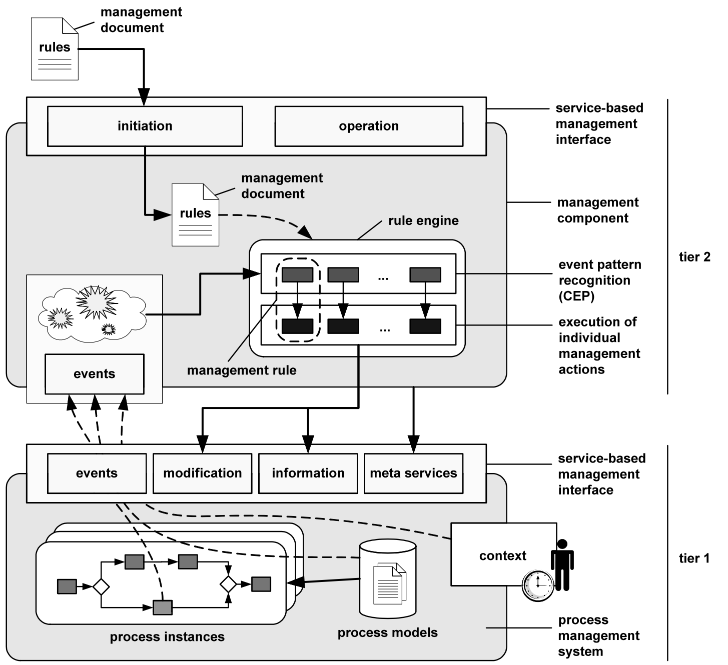


Figure 5: Management component to support customized management actions

ment document as complex situations and actions. An example for such a situation-action pair is monitoring the duration of a specific activity (*object*) and, in case a specified amount of time has passed and no progress becomes visible (*situation*), to restart the activity (*action*). However, also monitoring rules that do not influence the execution of the process are possible (e.g. after each activity, its performer, duration and current location should be logged) or distribution decisions can be supported (e.g. if the workload exceeds a specified threshold, the process should be transferred to a process engine with a better capacity).

Listing 1 shows the general syntax of a management rule as a part of the management document. For administration purposes, each management rule has a *name* and, optionally, a *description*. The *rule pattern* holds an event pattern to determine if a complex situation has occurred or not. The *rule action* specifies the service to be executed, including parameters for the service call if necessary. Encapsulated as a composite service, even complex actions can be defined. Furthermore, arbitrary system-external services, such as sending an email, can be referenced.

```
MANAGEMENT-RULES
  MANAGEMENT-RULE
     NAME         : <String>
     [DESCRIPTION : <String>]
     RULE-PATTERN : <Event-Pattern>
     RULE-ACTION  : <Service-Invocation>
  END MANAGEMENT-RULE
...
END MANAGEMENT-RULES
```

Listing 1: Structure of management rules

The management document is passed to the management component and the system returns a management identifier as a reference to the management document. Thus, the customer can adapt the management rules later if necessary. Interpretation and processing of the management rules are executed by a rule engine (cp. Section 3.3). Relevant events are subscribed and event notifications are passed to the rule engine in order to perform the pattern matching. If a specified pattern is recognized, the rule engine initiates the execution of the corresponding actions.

Besides the management rules (line 18 of Listing 2), the management document holds additional information required for correlation, assignment and execution of processes and rules. Therefore, *general information* (lines 3-7 of Listing 2) contains a *management endpoint* as the unique identifier of the process management system to be supervised, and a *management mode* which defines when the management should end. As management starts with passing the management document (i.e. the rule engine starts listening to the specified events) it can either terminate automatically when all process instances are finished (management mode = "system") or it can explicitly be terminated by the customer (management mode ="user"). The latter is relevant if the management should also observe the process engine as a candidate for further distributions, if process history data is required later (i.e. for evaluation) or if the process model can be instantiated again from the outside (which is e.g. the case for WS-BPEL processes which deploy their own service interface for the initiation of new process instances). In case of an automatic termination, the customer can optionally specify a *notification endpoint*. Termination of the management plays an important role, because here all rule patterns have to be removed from the rule engine, and the associated event subscriptions have to be cancelled.

```
1  MANAGEMENT-DOCUMENT
2
3    GENERAL-INFORMATION
4        MANAGEMENT-ENDPOINT         : <URL>
5        MANAGEMENT-MODE             : "system"|"user"
6        [NOTIFICATION-ENDPOINT      : <URL>]
7    END GENERAL-INFORMATION
8
9    INSTANTIATION-INFORMATION
10      PROCESS-MODEL-REFERENCE     : <STRING>
11      LOCAL-INSTANCE-REFERENCE    : <STRING>
12      [INSTANTIATION-TIME         : <DATE>]
13      [INSTANTIATION-DELAY        : <INTEGER>]
14      [INSTANTIATION-PARAMETERS]
15      [BLOCKING-EVENT-TYPES]
16   END INSTANTIATION-INFORMATION
17
18   MANAGEMENT-RULES
19
20 END MANAGEMENT-DOCUMENT
```

Listing 2: Structure of management document

The part of the *instantiation information* (cp. lines 9-16 in Listing 2) contains relevant data about the process instances. It holds the reference to the associated process model (*process model reference*) and a placeholder for the process instances (*local instance reference*) which do not exist at the time of deployment, but which need to be referenced within the rule patterns and actions for instance management. In case only one instance is distributed the process can optionally be started immediately, at a specified point of *time* or after a specified *delay*. In this case, also the *parameters* for process instantiation have to be passed. Finally, the management document specifies which events should be able to block the execution of a process instance (cp. line 15 in Listing 2). Such *blocking events* are required to enable immediate reactions where the process engine must not continue execution of the process. Blocking events are only relevant for the monitoring of process instances and are thus also part of the instantiation information.

In order to allow customizing the location of decision-making, processing of events and derivation of management reactions can take place on the remote system or at the customer's site. In the first case, the management document has to be transferred to the remote system, all events are caught locally and management actions are carried out by the partner system. Here, in general, management data does not have to be transferred over the network and consequently, the delay resulting from management is minimized. This option is well suited in case mobile participants are involved and network connection is temporarily unavailable. In the second case, all information and/or events are transferred to the customer and management reactions are determined here. This is required if e.g. management decisions are confidential or need approval by a human operator. However, this strategy may decrease performance of process execution. Furthermore, the customer has to run and maintain the management component in order to make decisions – which may not be desired e.g. in the case of BPM-as-a-Service scenarios (cp. Figure 1(d)). An attractive alternative is, however, the combination of both strategies, e.g. having general monitoring data collected and processed by the remote system and calling-back to the customer only in case of infrequent severe problems.

3.3 Implementation

In order to use the WSDM framework, the model of relevant characteristics and relationships of process management system, process models, instances and context has been represented as a *WSDM resource properties document* which is specified in XML. Furthermore, XML-Schema (XSD) is used to specify structure and data type of each property. According to the meta-description established in Section 3.1, an example for the representation of the property "WorkloadInfo" is depicted in Listing 3 and 4. The resource properties can be accessed using the WSDM web service operations *GetResourceProperty* and *UpdateResourceProperty* as well as a set of additional operations, e.g. for cancellation of process instances, which are altogether included in the associated web service description (WSDL). The WSDL file also contains the location where the service can be accessed, e.g. a URL. Finally, WS-Notification (WSN) topics for subscription of events have been specified and included, and for each event it is specified whether it should be allowed to block the process execution in order to enable a direct reaction.

```
<Property name="tns:WorkloadInfo" modifiability="read-only"
          mutability="mutable" meta:mutfreq="meta:minutes">
    <meta:availability>meta:always</meta:availability>
</Property>
```

Listing 3: Example for the meta-description of a BPM resource property within WSDM

```
<xsd:complexType name="WorkloadInfo">
  <xsd:sequence>
     <xsd:element name="RunningInstances" type="xsd:int">
     <xsd:element name="CPULoad" type="xsd:float">
  </xsd:sequence>
</xsd:complexType>
```

Listing 4: Example for the schema definition of a BPM resource property within WSDM

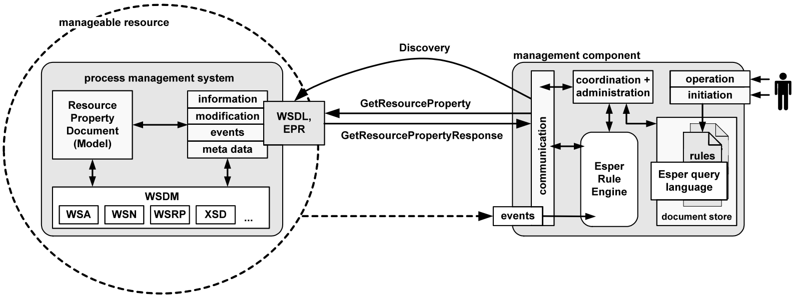


Figure 6: Prototype implementation using WSDM and Esper

The left side of Figure 6 shows an overview of the implementation with WSDM. In order to interact with the manageable resource, the management consumer only requires the *Endpoint Reference (EPR)* of the process management system, i.e. the information from the WSDL file. After that, read-only or write requests as well as subscriptions for events can be carried out by requesting a property of the resource properties document. The requested resource respectively replies with a *GetResourcePropertyResponse* resp. *UpdateResourcePropertyResponse* message in case of a successful operation or with an exception in case of an error. In case the consumer wants to subscribe for an event, besides the topic also the type of the event can be specified, i.e. if the event should block the execution of the process or not.

On side of the management component (cp. right side of Figure 6), the management document is interpreted and stored for the time of its validity. The *coordination and administration module* is now responsible for the discovery of the specified management endpoint, to subscribe for the required events and to manage time constraints and deadlines. The received event stream is processed and tested against the user-defined event patterns. In the prototype implementation, the complex event processing is done by the existing Esper rule engine (cp. Section 2). As Esper expects expressions in the SQL-based Esper query language, the abstract *event pattern* part of the management rules (cp. line 5 of Listing 1) is represented by the respective terms of this language. A simplified example for a complete management rule is presented in Listing 5. In this case, the process variable named *deadline* within all instances of the process model with id='1' is updated if the execution of an activity with id=4 takes longer than 60 seconds.

```
<Rule name="ExtendDeadline">
  <Trigger>
     SELECT * FROM PATTERN
      [EVERY (e1=ActivityStarted(activityId="4",modelId="1")
             -> TIMER:INTERVAL(60 SEC)
             -> NOT e2=ActivityFinished(activityId="4",modelId="1"))]
      WHERE e1.instanceId=e2.instanceId
  </Trigger>
  <Action>
    <Service epr="http://example.com/bpms.wsdl" operation="UpdateResourceProperty">
       <Param type="PropertyName"><Value>DataField</Value></Param>
       <Param type="ProcessInstanceID"><Value>%{e1.instanceId}</Value></Param>
       <Param type="DataFieldName"><Value>deadline</Value></Param>
       <Param type="DataValue"><Value>60</Value></Param>
    </Service>
  </Action>
  <Trigger>
```

Listing 5: Example management rule with Esper event pattern and WSDM service invocation

4 Evaluation

So far, the prototype implementation has been applied to two existing process management systems: first to the DEMAC [ZKL09] process engine which uses XPDL processes and supports the runtime migration of process instances and, second, to the Sliver [HH+06] process engine which uses a subset of WS-BPEL processes. The following example scenario is used to show the main observations and results also in comparison to two previous approaches.

4.1 Example Scenario

Figure 7 shows an example from the *eErasmus eHigher Education (eEH)* project [JL06], which is an international exchange program of higher education institutes among EU countries. In order to facilitate a uniform exchange of students joining this program, a standardized process is proposed for participating universities. The simplified functional process used here involves subcontracting the host university for *approving the credentials* necessary for taking courses there, allowing to take *courses and exams* until a specified deadline and *preparing the credentials* achieved at the host university in order to acknowledge them at the home university.

The distributed execution involves several management requirements which are *expected in advance*, i.e. before execution of the process starts: (R_1) The host university is paid a certain amount of money for each student and for the associated administration effort. Therefore, the duration of each activity executed by the host university has to be logged. (R_2) In order to handle potential errors in time, the home university wants to be sure that the foreign university has received the sub-process and is able to execute it, and, (R_3) if duration of an activity expected as critical (here *preparation of credentials*) exceeds the average time for executing a task, (R_4) the activity should be skipped in order to at least allow the control flow of the process to return to the calling system. (R_5) As it sometimes happens that the deadline for taking courses is adapted by the host university, e.g. because the student gets ill, the home university wants to know about such events in order to avoid automatic removal from the home register of students. In addition, there are a number of *unexpected occurrences* during the runtime of this rather long-running (i.e. several months) process: First, a financial aid program asks about the status of the student's overall study (R_6). Second, the student has married and his/her name has to be adapted (R_7).

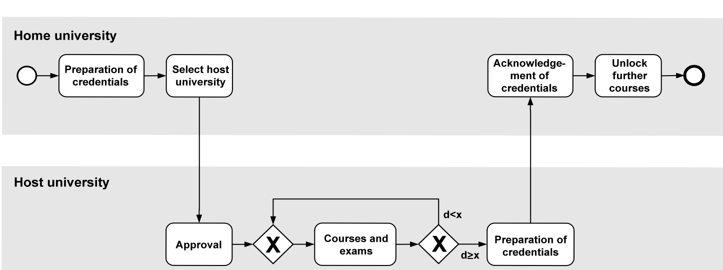
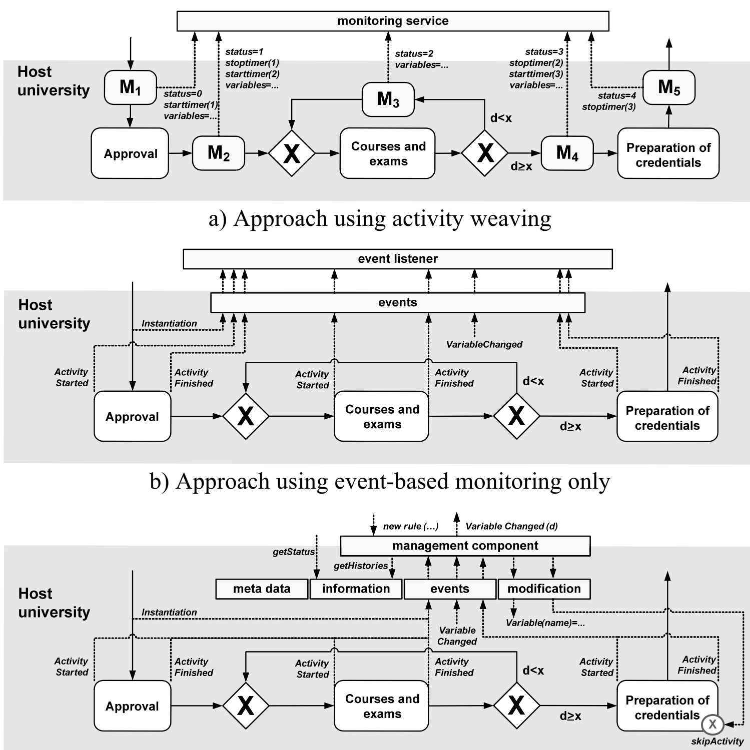


Figure 7: eErasmus example process

4.2 Comparison and Results

Figure 8 shows the realization of the monitored process instance with weaving of monitoring activities, event-based monitoring, and the ad-hoc management approach proposed here. Results are summarized in Table 1. It shows that monitoring aspects which are known in advance, such as measuring of the duration of predefined activities, the start of instance execution and the observation of variable value modifications can be realized by the design time insertion of respective monitoring activities (timer activities and passing of variables values to the central monitoring service) and by the event-based monitoring and the ad-hoc management approach (by subscription of the respective events). The detection of abnormal activity duration can be realized by the ad-hoc management as a complex rule involving also additional information about previous process instances executed on this system and calculating their average time of execution. This is neither possible by a system which makes use of events only (the events of other process instances have not been captured before) nor by activity weaving (histories of other process instances are not visible in the monitored process instance). Skipping critical activities is also a problem, because event-based monitoring does not offer control functionalities at all, and activity weaving cannot skip crashed activities by weaving an "end activity" because in this case control flow will not reach this activity.



a) Approach using activity weaving

b) Approach using event-based monitoring only

c) Approach using ad-hoc management

Figure 8: Different realizations of the scenario-based management requirements

Table 1: Applicability of management requirements during execution of the example process

Management requirement	Ad-hoc management	Event-based monitoring	Activity weaving
(R_1) Duration of activities	+	+	+
(R_2) Instance started	+	+	+
(R_3) Detect critical activity duration	+	o	o
(R_4) Skip critical activity if necessary	+	-	-
(R_5) Observe variable value	+	+	+
(R_6) Ad-hoc status retrieval	+	o	o
(R_7) Ad-hoc variable value modification	+	-	-

Considering unexpected occurrences, the ad-hoc management shows its biggest advantage: The status retrieval can be made by calling the process's resource property *process status* and interesting *data values* directly. Both activity weaving and event-based monitoring can provide this data only in case a monitoring activity is inserted after each functional activity resp. all available events have been subscribed. Therefore, it is more or less a coincidence if such requests can be fulfilled as they cannot be determined in advance and relevant properties have to be weaved/subscribed before runtime. The ad-hoc variable modification is also not possible because of missing runtime modification operations. However, even by using the ad-hoc management approach, the process manager has to be careful not to violate the integrity of the process. Therefore, in case of the modification of the student's name, the process manager should abstain from calling the modification interface directly, but better update the management document by inserting a new rule – e.g. to wait until the current activity is finished (subscribe *ActivityFinished* as a blocking event), perform the modification, and then resume execution.

Considering non-functional characteristics, it shows that desired separation between business logic and management logic can be achieved by event-based and ad-hoc management approaches (as the original business process does not have to be changed), but not by activity weaving (cp. Figure 8). Especially in the context of mobile process management, the approach of activity weaving furthermore proves to be very instable (i.e. if the monitoring service is not available, the process execution is delayed or even fails). For the event-based approach, no delays effected by the management are visible at all – however no reactions are possible and thus events can be emitted in parallel to an ongoing process execution without delay. Compared with both event-based and ad-hoc management approaches, activity weaving has, however, the advantage that no system modifications, security mechanisms or agreements are necessary.

5 Conclusion

In today's highly dynamic business networks customized monitoring and controlling options for distributed business processes gain increasing importance. This paper advances existing approaches for the management of such processes by presenting a concept to not only passively observe the behaviour of business processes running on a remote process management system but also to enable quick automatic and spontaneous reactions on the basis of a service-based management interface. Thereby, the presented approach allows for increased flexibility during process execution and for the integration of valuable functionalities of remote process management systems which have not been exploited before. However, process managers have to be aware of their respective new potential, e.g. by influencing process execution during runtime which may lead to undesired side effects. Furthermore, the presented approach has to be secured so that both provider as well as the consumer of distributed process management are protected in a sufficient way. Therefore, the conceptualization and application of protective measures and customizable security and privacy mechanisms are an important part of future work.

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Understanding the Value of Business Process Configuration

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Abstract. In order to deliver effective services, providers are being advised to 'innovate' their service delivery systems. Innovation in this context often refers to technology, technique or restructuring improvements. However, the difficulty is that in the modern organisation, service delivery is dispersed across a complex network of numerous departments and units. There are greater pressures on organisational service systems to deliver a higher quality and more efficient service. Management must attempt to develop a greater understanding of organisational process and where improvements may be made using business process management (BPM). The network approach ultimately makes service innovations more difficult to implement. Thus, the purpose of this study is to investigate how service innovation is managed across a service network. Specifically, we examine the effectiveness of a technique called 'social network analysis' (SNA) in extending business process management to enhance the manageability of network based services. This paper sets out to provide a state of the art literature review on the short fallings of our ability to understand what triggers business value. It examines the effects of our inability to understand the influence of business process behaviour on service innovation. It also provides a conceptual account of how SNA can be a powerful tool for managers to understand organisational network performance and service interaction (e.g. behavioural, functional, and structural).

1 Introduction

The growth in service science as a discipline has underscored the need to investigate the contributory value of business processes and its influence on how a service system (including people, technology, and organisations) affects the delivery of organisational performance. Within organisational and technological management theory, understanding and measuring value (i.e. application of competences) of service networks is considered one of the key problems which prevent the sustainability of organisational growth. We refer to value as "the adaptability and survivability of the beneficiary system" [VMA08] (p. 148). Understanding the value of this infrastructure after investing often proves to be an even greater challenge [WSB02]. Therefore, assessing the value of the service processes is of critical importance. Service science explores the value co-creation of interactions between service systems (for example, [SM08], [VMA08]). As service networks continue to grow, understanding the dynamic exchange of resources which creates "value", determined through specific relationships and interactivity between service systems is of significant importance. This paper sets out to provide a state of the art literature review on the short fallings of our ability to understand what triggers business value. It examines the effects of our inability to understand the influence of business process behaviour on service innovation.

It also provides a conceptual account of how social network analysis (SNA) can be a powerful tool for managers to understand organisational network performance and service interaction (behavioural, functional, and structural).

2 Background to the Research

Our traditional understandings of the '*organisation*', with solid boundaries and internally focused on operations, time, and individuality are becoming less apparent today. As competitive advantages of single organisational strategies continue to erode over recent years, organisations are experiencing greater demands to operate with increased innovation, collaboration, scalability, efficiency, agility, and virtuality (for example, [Z97], [MSB99], [RK02], [BH03], [AC05], [BM06], [F06], [K07], [VWVV07], [SMBG07], [C07], [G09], [H09]). In fact, services are now the dominant contributor to the developed economies. The business landscape has significantly changed, i.e. a shift from a goods-dominant logic towards a service-dominant logic ([N01], [VMA08]). It is evident that a scientific understanding of modern services is undeveloped and may even be described as an unexplored topic. This has sought the introduction of "*service science*" which attempts to address this problem. Service science is an attempt to "study the application of the resources of one or more systems for the benefit of another system in economic exchange" (p. 2) [SMBG07]. One of the fundamental objectives of service science is to understand the mechanics of service networks and define how and why they generate value.

[SMBG07] summarises one of the core problems in understanding the dynamics and complexity of service science: "*powerful dynamics are in play around the world when it comes to applying resources effectively to solve problems and create value*" (p. 10). Value (for example, economic, social, and interaction exchange) is the core of organisational sustainability. Over the past few years business practices have changed dramatically for several reasons including; globalisation, world financial crisis, accessibility of a global educated and mobile workforce, technological advances (*'death of distance'*), and global outsourcing. Understanding how these influences have distorted our understanding of business plays a significant part on how we interpret service networks. Many of these changes require that we view business with a new mindset to understand the interactions of global and electronic infrastructure which supports service operations. Transparency within service operations is envisioned as a critical factor within service innovation [CS06]. Organisations are under increased pressure to adapt their business processes at a much faster pace than they have ever experienced before [PBLDKL08]. Understanding the value of service network infrastructure after heavy investments often proves to be an even greater challenge. In addition, organisations must monitor what is often described as the 'paper-based system' which is only too common through many organisational service systems. There is little evidence to suggest the organisations understand whether their service networks are operating at an optimum level and how can they demonstrate how value is created and measured.

3 Business Processes Defined

The overall objective of implementing a business process is an attempt to improve business. Thus, we must understand the dimensions (for example, structural, behavioural, and functional) of the business process and its contribution towards organisational performance.

The term '*business process*' has been well documented across literature in the hope to shape and reshape a more universally accepted meaning of the term. For example, [D93], (p.5) defines a business process as "*...a structured, measured set of activities designed to produce a specific output for a particular customer of market*". In addition, [HC93], (p.35) defines a business process as a: *"...collection of activities that takes one or more kinds of input and creates an output that is of value to the customer*". In more recent years, [SF03] define a business process as, "*…the complete, end-to-end, dynamically coordinated set of collaborative and transactional activities that deliver value to customers*." [SF03] dissect their definition, and extract the key characteristics of business processes. They specify eight characteristics of business process as follows:

1. ***Large and complex:*** involving the end-to-end flow of materials, information and business commitments.
2. ***Dynamic:*** responding to demands from customers and to changing market conditions.
3. ***Widely distributed and customised across boundaries:*** within and between organisations, often spanning multiple applications on disparate technology platforms.

4. ***Long-running:*** a single instance of a process such as "order to cash" or "develop product" may run for months or even years.
5. ***Automated:*** at least in part. Routine or mundane activities are performed by computers whenever possible, for the sake of speed and reliability.
6. ***Both "business" and "technical" in nature:*** IT processes are a subset of business processes and provide support to larger processes involving both people and machines.
7. ***Dependent on and supportive of the intelligence and judgment of humans:*** the tasks that are too unstructured for a computer or require personal interaction with customers are performed by people. The information flowing through the automated systems can support people in solving problems and creating strategies to take advantage of market opportunities.
8. ***Difficult to make visible***: these processes are often undocumented and embedded in the organization. Even if they are documented the definition is maintained independently of the systems that support them.

The last characteristic is an interesting flaw within business process management ('difficult to make visible'). If we can understand the behaviour of business processes, surely we can offer a method to management to visualise the business processes behaviour and what influence (enables or inhibits) process innovation. After all, [P03], defines a business process as "*a set of logically related tasks performed to achieve a well defined business outcome*" (p. 49). In addition, [P07] explains that a business process comprises of a set of logically related tasks performed to achieve a well-defined business outcome that determines the results to be achieved, the context of the activities, the relationships between the activities, and the interactions with other processes and resources. Therefore, the behaviour exhibited within business process management, can provide us with a critical insight as to what influences organisational/service performance. Understanding this, relates back to how [CKO92] uses the term 'business process reengineering', and defines it as '*the redesign of an organisation's business processes to make them more efficient*'.

4 Business Process Management

As the current business practices are carried out, we know that taking a reactive stance in today's business environment is no longer sustainable. In addition, we must also look beyond the
tangible assets within business processes. [A03], cautions that managers find it difficult to understand many of the critical intangible metrics of organisational networks (p.5):

> *"Companies and economists struggle to develop new scorecards, metrics, and analytics that will provide leading indicators for how well a company or country is building capability for the future".*

Although Business Process Reengineering (BPR) was quickly embraced, organisations failed to reap its potential promise [H97]. One of our latest organisational theoretical developments is Business Process Management (BPM). BPM has adopted many definitions, however [DM97], report that no single solution exists to meet organisational performance needs. The value driven metrics of BPM therefore requires further attention. [LD98] (p. 217), offers a definition for BPM as:

> *"...a customer-focused approach to the systematic management, measurement and improvement of all company processes."*

BPM is the latest development in extending our understanding of organisational management. BPM has emerged as one of the major new developments within organisations to support our understanding of the evolution and interaction of process-oriented business applications and information systems. BPM has encapsulated many definitions over time, which identified the need to enhance a specific process or a number of processes, to allow an organisation to operate more efficiently. For example, [EHLB95], state that BPM consists of *"...systematic, structured approaches to analyse, improve, control, and manage processes with the aim of improving the quality of products and services*." The 'value' of BPM was captured in the [LD98], case study as a method of "*measuring the core processes, analysing what works and what doesn't and improving them*" (p. 219). They also identify three critical factors which contribute to the success of BPM: (1) process discipline (correct and consistent application of business processes), (2) process improvement, and (3) cross-process integration. The concept of value-driven processes often refers to services within a business network that executes a business process to produce economic value while monitoring cost, quality and time parameters within business processes.

Therefore, BPM should be considered as a tool with huge potential and not a fad of managerial toolsets [DM97]. However, according to [A03], one of the main problems of successfully managing organisations today is that it has become more complex due to the changing nature, structure and identity of organisations. One of the major emphases realised today in achieving a competitive advantage is in business intelligence (BI), through communicative and collaborative networks and knowledge management (KM) across the wider organisational spectrum ([D88], [D06], [EL05]. [WDLBNVP09], explore the use of Business Activity Monitoring (BAM) to map service choreography and monitoring agreements. To assist business analysts and managers to extract knowledge, there are often a number of BI tools available (e.g. IBM Cognos 8 is a single service-oriented architecture). However, these are limited in their functionality (i.e. ability to extract unstructured data and limited to focus on a single organisation rather than an entire network). While the current limited view is sufficient to address specific problems, a complete and holistic view of the BPM modelling space is required in order to avoid isolated solutions by providing an overall view over the whole organisational network [PBLDKL08]. This is more evident in the service-dominant logic business environment.

4.1 Business Process Management – The Problems

Organisational change, more specifically business process change is a critical activity across service networks to accommodate the reoccurring trends across the business landscape.

However, change can take place on many dimensions, i.e. through continuous process improvements, or through radical rethinking a renewal of the business model and how business activity reflects this change. To look at BPM through a much broader lens, we revisit what [A04] suggests that BPM supports:

> *"...business processes using methods, techniques, and software to design, enact, control, and analyse operational processes involving humans, organisations, applications, documents and other sources of information".*

Therefore, the governance, chorography and management of human ad technological interaction are of critical importance to understand the competency of a service network. However, the literature indicates that there are several issues with our current understanding of BPM. For example, [PBLDKL08], state that BPM suffers from a lack of automation which '*could*' support the transition between the business domain and the information technology domain.

We should also re-examine the goal of BPM as highlighted by [BCGMT05], the goal towards achieving business process automation, is motivated by numerous reason, including; creating opportunities in relation to cost savings and higher quality, more reliable executions, which has consequently generated the need for integrating the different enterprise applications involved in such processes. Within the [S08], BPM has received much attention. An extensive account of BPM describes a number of problems which are listed as follows:

1. Existing generation BPM technologies do not address quickly emerging requirements of complex, service enabled applications, involving several organisations.
2. BPM deployments are narrow in scope
3. Existing BPM adopt an organisation-centric view
4. Only provide improvements to business functions of a single organisation
5. Becomes a problem if managers are trying to apply existing methods to encompass agility to span service networks across organisational boundaries.

In addition, existing methodologies or concepts (for example, BPEL) used within service engineering fail to capture and represent human aspects and other data including, the user goals, tasks, motivations and characteristics, and lacks information about the actors ability, actions, motivations. We wish to take this a step further and explain the need for more dynamic and explorative methodologies to understand the underlying behavioural patterns of service networks.

5 The Emergence of Service Science

Information and communication technology (ICT) has been charged as one of the main contributors for organisational flattening [F06] and the evolvement of service science [CS06]. The wealth of information available on people and their roles, technology and processes, and organisations and activity has never been greater, nor has the prospect to (re)configure them into service relationships to create new value. The information revolution has given birth to new economies structured around processes and flows of data, information, knowledge, and more recently, people ([H89], [K89], [SG89], and [REMCV02]). Thus, information technology plays a significant role in the enabling or inhibiting of business process behaviour across service networks [WSB02]. To exasperate this, organisational boundaries have been redefined, creating larger 'change' patterns [A03]. Despite all the attention however, the contributory value of services to organisations is still poorly understood. Considering the promise of BPM, understanding the value of service systems is prominent across several sectors of our economy.

The concept of service science has become very popular throughout organisational and information systems literature. Service science is often referred to as a discipline which scientifically explores the theory and mechanisms required for the distribution of interoperable services. [SM08], state that "*service science aims to explain and improve interactions in which multiple entities work together to achieve a win-win outcome or mutual benefits....[as] value co-creation as a change or set of related changes that people prefer and realise a result of their communication, planning, or other purposeful and knowledge-intensive interactions*". This theoretical development is considered important to support today's dynamic and networked business world. However, considering that service science is a relatively new field, much of the literature attempts to understand the importance of service science and attempts to define what service science constitutes rather than prescribe precise methods to improve business practice. BPM could provide a significant contribution here with the emergence of a modern theoretical view of the business world (i.e. service science) and the application of business process technology (i.e. BPM). There has been a significant shift on the focus of a technological-centric view of business to a more holistic encompassment of business processes, human behaviour, and technology.

5.1 The Change in Business Landscape

Technological advances are the main driving forces of service science especially across end-to-end electronic communication channels and service-oriented business models. This has afforded organisations the opportunity to break-up or to 'unbundle' and the ability to put together or 'rebundle' specific processes [N01]. Most notably, IKEA have become world class in their ability to unbundle their system of value creation or reallocate different economic actors, i.e. the customer now plays a significant role in indentifying, transporting, and assembling IKEA furniture. Witnessing the dramatic change in business, it raises two core questions within service science and one in which this within BPM: what is the contributory value of business processes across a service network, and how do these contributions influence service innovation? As [F05] reports, "*services have little value if others cannot discover, access, and make use of them*" (p. 814). Thus, service science explores how an organisation conducts business and how we can optimise process influence on the delivery of a service. To gain a better understanding of how we might address these questions, we must first ask what constitutes as a service. Within the IS discipline, little research exists towards the exploration into the influence of ICT in service design and delivery, which suggest the need to revisit the modern concept of the 'service'. In 1977, [H77] defines a service as: "*a change in the condition of a person, or a good belonging to some economic entity, brought about as a result the activity of some other economic entity, with the approval of the first person or economic entity.*" Economics typically attributes transactional value or market value to assets, good or service which is difficult to set by an individual economic actor [N01]. A market handles these complexities and establishes the market value which is determined by the buyer and seller. Within a service environment, a service may be viewed as the networked behaviour to offer a specific capability from one party to another through a predefined protocol or service compositions.

Defined by [FF04], a service is a "*...time-perishable, intangible experiences performed for a customer acting in the role of a co-producer*." Services are a fundamental factor in every organisation, for example, health care, education, retail, and finance. Services extend business processes and business functionality within (cross-departmental) and outside (cross-organisational) of an organisation. The behaviour in which it does so indicates the value of process within the service network.

A service is often referred to as "*protocols plus behaviour*" [SMBG07]. Service activities include co-generated exchanges of largely intangible assets, collective coordination, and integration of knowledge under negotiated conditions between the provider and the supplier. According to [F05] "creating a service involves describing, in some conventional manner, the operations that the service supports; defining the protocol used to invoke those operations over the Internet; and operating a server to process information requests" (p. 814). The complexity of the service system or on-demand business architecture is often misunderstood which requires the introduction of new theoretical developments. Therefore, managers must begin to view services through a scientific lens to construct reusable and standardised modelling methods to evaluate and govern service networks and manage dynamic business process.

5.2 Service Configuration

Through this new lens, we propose that service configuration is the core logic which should support service process management. Service configuration presents us with the ability to (re)construct reusable methods and process patterns or blueprints to support service networks through the visualisation of dynamic business process. The concept of service configurability has been well documented throughout business and information systems literature. For example, [N01] (p. 59) reports "*a technological breakthrough in itself may be enough to trigger reconfiguration*", ... [and] *"creates cases of reconfiguration which seems to stem from a new design vision of the 'industry' or broader system of value creation"* (p. 61), e.g. IKEA, Apple, and Microsoft. Technology often serves to reconfigure business practice and processes albeit often without a strategic plan to reframe *business practice to align with emerging business patterns.* In addition, [N01] illustrates the dramatic shift in business logic from an assets dominant perspective to a reconfiguration of value-creating system as depicted in figure 1 below. Figure 1 above illustrates that significant towards a new strategic logic of the 'economy of reconfiguration'. The main emphasis here is the competence to organise value creation extending beyond the traditional boundaries. This is largely due to the affordance of information technology and the virtual organisational infrastructures. Thus the "*reconfiguration of value-creating systems*" shifts our focus on the customer from being that of a recipient to being the co-producer and co-designer of value creation. These relationships between the service provider and client open up new possibilities on the generation of service innovation. Across academia and industry we are beginning to recognise the significance of service innovation and service systems within the global economy. One of the fundamental objectives of mapping these relationships is to understand the underlying mechanics of service networks and define how and why they generate value.

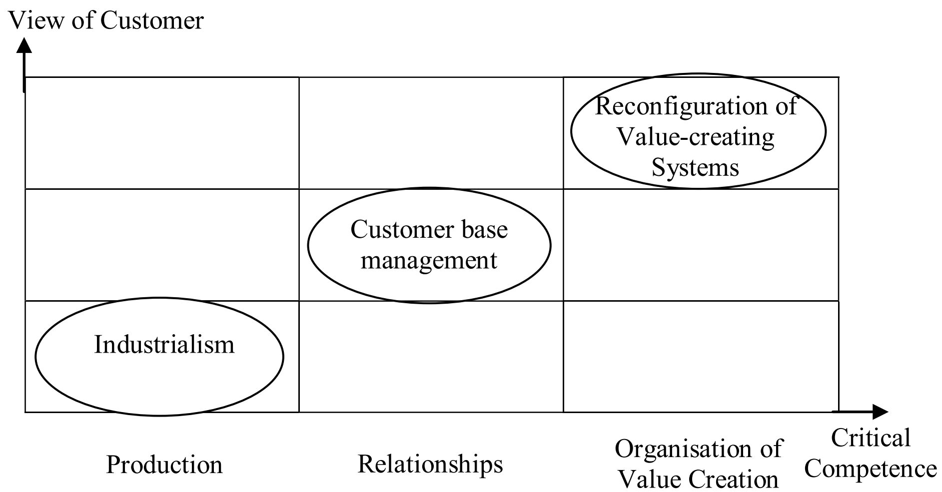

Figure. 1 - Evolution of Strategic Paradigms (extracted from Normann 2001)

5.3 Service Science and Organisation

The introduction of service science indicates the need to theoretically and empirically explore the concept of services in today's global and digital economy. Organisations are beginning to move away from the traditional corporate hub of business practice towards a more diffused and distributed web of relationships and agile alliances. [N01] introduces the '*principle of density'*, which is mainly driven by technology and the shift in managers mindsets in restructuring or reconfiguration of new 'opportunities' This refers to the best combination of resources which are mobilised from a particular situation in a given time and place, independent of location, to create the optimum value/cost result, for example, the mobile phone [N01]. However, we fail to understand the contributory value of service networks and the influence of service relationships. For example, [A05] reports that within the U.S., "*10-50% of general service business contracts do not meet client expectations*" (p. 9). This may have a greater affect on service networks. For example, [SMBG07], report that "*service systems are connected to other service systems via value propositions*" (p. 4). Understanding the mechanisms and theory of managing service business models and processes adopted across many organisations require that we approach service networks with a scientific lens. It is clear throughout literature that manager's continue to face serious issues in managing a completely invisible asset (i.e. service network) which inhibits their ability to monitor and exploit the value of service networks. In addition, managers fail to determine the influence of both human interaction and technology on service networks.

Service systems continuously evolve and are (re)designed in response to change but one of the fundamental problems is their inability identify shortfalls and fail to optimise the return on investment across entity interactions with unpredictable outcomes [SMBG07]. In addition, we propose the need to work towards the introduction of agility within service networks to identify changes and respond proactively to this information. The value of service transactions often go unknown, although managers perceive that they understand the possible investment of executing an effective service, for example, distributing software or distributing valuable information [N01]. This shifts the focus from the tangible good to viewing the "*transaction as an investment in a future revenue-generating relationship*" [N01] (p. 38). This suggests that this phenomenon is a strong indicator of the shift from the industrial strategic logic towards higher logic of customer-base management.

The introduction of service science challenges our traditional understandings of service management. The unprecedented growth in service-based business processes over a short period of time has underscored the need for understanding the mechanisms and theorising the business models and business process management adopted across many organisations today. Understanding the functionality of these networks and the challenge of managing and co-coordinating their relationships is becoming more complex. As SSME theory is at a relatively early stage, it cannot adequately prescribe methods to manage complex service processes and their relationships. Thus, the questions emerge: how do we manage service networks and how can we enhance their capabilities and business value? This question will be further explored in section seven.

Understanding the value of service network relationships, especially from a human and technological perspective can prove to be extremely problematic. In addition, the literature indicates that the tools to create, track, and manage outsourcing business process opportunities are incompatible, slow, and difficult to use. To exasperate this, it is also reported throughout literature that critical business data is incorrectly collected, shared, standardised, or analysed to provide business intelligence.

6 Business Process Management in Service Science

BPM across service networks should be also concerned with improving manager's ability to predict risk, estimate their effects, and reduce uncertainty through modelling the value-exchange which results from provider and client interaction (intellectual, behavioural, economic, and/or social activities). [CS06], identify several key foundations within service science, including understanding the level of interaction, the nature of knowledge, and the exploitation of ICT and transparency in service networks. The nature of knowledge refers to both codified (information) and tacit (experience) which are often difficult to model and understand the transfer, partition, and reuse of knowledge which are considered fundamental building blocks within the economies of service science [CS06]. One of the critical characteristic within these services is 'differentiation' or 'uniqueness' in order to allow a service to remain sustainable. Across large service networks, reorganising, consulting, and exchanging on business processes is becoming more important within service science. Understanding the complexity of network structures, process patterns, and methods to improve network performance is critical to the success of service system, for both the service provider and client.

7 Applying Social Network Analysis to Business Process Management

In recent years there has been significant interest in our ability to effectively and efficiently manage and (re)engineer services. It is clear throughout literature that manager's continue to face serious issues in managing '*a completely invisible asset*' (i.e. service network) which inhibits their ability to monitor and exploit the value of innovation. Social network analysis (SNA) is an approach and set of techniques which studies the exchange of resources (for example, information) among actors. SNA focuses on patterns of relations among nodes such as people, groups, organisations, or information systems ([B82], [WB88], [S91], and [WF94]). SNA demonstrates the value of ties and relationships between each node to provide a visual and mathematical representation of interaction and exchanges which influence behaviour. Managers realise that the key to continued success is within their understanding of how workflows and business processes can be optimised (e.g. [P02]). [BK06], reports that SNA may allow organisations, in financial trouble, to gain vital insights and discover survival prospects. In 2009, [H09] demonstrates that by studying IT-enabled processes, we can identify the contribution of IT to business process success, or improved performance. One of the main benefits of SNA is its ability to provide a methodology to gain deeper insight of how structural regularities influence behaviour [OR02].

Therefore, SNA is a very fitting methodology to deploy within this research to uncover more 'truths' as to the activities and their business process patterns. Thus, organisations can gain continuous and insightful feedback on how business processes are actually being executed, and where 'gaps' or 'pain-points' may exist. This enables BPM to overcome three major problems:

1. The need to isolate and measure the impact of IT in order to plan and design how the technology should support the business process across a service network.
2. The need to measure the success of IT-enabled BPM efforts as they are being implemented.
3. Determine how service-orientated process patterns influence the value configurability of service system networks.

In addition, [CP04] summarise the common social network applications including, supporting partnership and alliances, assessing strategy execution, improving strategic decision in top leadership networks, integrating networks across core processes, promote innovation, ensuring integration post-merger or large scale change, and developing communities of practice. Thus, BPM can benefit from the application of SNA. More notable, SNA can support BPM to discover business process dynamic behaviour while identifying where strengths, weaknesses, opportunities, and/or threats lie across a service network using SNA metrics. Measuring business networks can provide valuable insight on the operating status of a service network and determine whether change may be required, or provide knowledge where change may cause further problems through SNA simulation. Business process modelling and the evaluation of various scenarios for improvement are the main driving factors of renovating business processes. SNA allows us to graphically capture organisational interaction, and can provide us with an insight into how people's understandings of business process are transferred onto their interactions. Thus, SNA provides an excellent methodology to offer managers a more simplified, practical, and reusable framework.

8 Conclusion

This paper provides a state of the art literature review and identifies some of the significant problems which emerge within BPM. In addition, the paper presents the need for BPM methodologies and techniques to adopt and simulate change within service-dominant logic. The justification for this is to understand how business processes influence service value and generates service innovation. The motivation is to propose the need to incorporate SNA techniques with BPM which presents managers with the ability to manage service network through the visualisation and simulation through the support of SNA and BPM combined to deliver a more robust and adaptive approach to managing complex service networks. This requires the development of a coherent framework to capture the value of service process behaviour. Through the affordance of SNA, this will allow us to define the characteristic of linkages to interpret key behavioural indictors. This will determine the structure and pattern of service process relationships and identify the influence (cause and consequence) of relationships embedded in the service network

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Deep Business Optimization: A Platform for Automated Process Optimization

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Abstract: The efficient and effective design, execution and adaption of its core processes is vital for the success of most businesses and a major source of competitive advantage. Despite this critical importance, process optimization today largely depends on manual analytics and the ability of business analysts to spot the "right" designs and areas of improvement. This is because current techniques typically fall short in three areas: they fail to integrate relevant data sources, they do not provide optimal analytical procedures and they leave it up to analysts to identify the best process design. Hence, we propose in this paper a platform that enables (semi-)automated process optimization during the process design, execution and analysis stages, based on insights from specialized analytical procedures running on an integrated warehouse containing both process and operational data. We further detail the analysis stage, as it provides the foundation for all other optimization stages.

1 Introduction

In this section, we first briefly discuss the reasons for and our understanding of process optimization within Business Process Management (BPM) and the role of analytics within this context. Based on this, we briefly analyse weaknesses in today's optimization tools and techniques and introduce our *deep Business Optimization Platform* as a means to address these weaknesses.

1.1 Business Process Optimization

In the past decade, businesses have moved from tweaking individual business functions towards optimizing entire business processes. Originally triggered by the growing significance of Information Technology and increasing globalization [HC93], this trend has - due to the increasing volatility of the economic environment and competition amongst businesses - continued to grow in significance. Hence, achieving superior process performance through BPM is nowadays one of the key sources of competitive advantage for businesses.

Stage	"Traditional" approach	dBOP approach	Benefits
Design	• No data or simulated data used as foundation	• New process is linked to existing data of similar processes	• Allows transfer of experiences from existing processes
	• Process design depends solely on analyst	• Pattern catalogue supports application of best practices	• Speeds up design process and improves process quality
Execution	• Decision making and staff assignment based on static models/roles	• Dynamic decision making based on analytics results	• Improves quality of decisions and staff assignment
	• Decisions only consider process data	• Decisions augmented by operational data	• Improves quality of decisions and staff assignment
Analysis	• Analysis only considers process execution data	• Process data integrated with operational data	• Enables discovery of "deep" insights that are not visible from process data
	• Analytics functions restricted to displaying basic information	• Specialized Data Mining and OLAP procedures used to extract "interesting" process properties	• Speeds up the analysis process and helps with discovering previously unknown optimization potentials

Figure 1: Comparison of traditional and *dBOP* optimization approach

Historically, process optimization in BPM has its roots in Business Process Reengineering (see [HC93], [Cha95]). Within this context, process optimization was often considered to be an exercise, where one static (process) model would be transformed into another static model. Within our work, we also include dynamic optimization - that is, optimization during process execution - so that we (similarly to e.g., [WVdAV04]) arrive at the following three stages of optimization within BPM:

1. **Design**: Design refers to determining the a priori (i.e., before execution) structure of the process. The goal is to design an optimal process based on "best practice" knowledge and experience/data from similar processes.
2. **Execution**: During the process execution, the goal of the optimization is to make optimal choices within the given process structure (e.g., allocation of optimal resources).
3. **Analysis**: The goal of this a posteriori redesign of the process is to change its structure in order to achieve optimal results with respect to the execution results.

1.2 Motivation for a Deep Business Optimization Platform

Despite the importance of process optimization, it is still often conducted in an ad hoc manner. Typically, when designing or analyzing a process, analysts try to get as much data about the process as possible (often in an unstructured way). Then, they try to "find" deficiencies as well as implement appropriate optimizations. There are a number of challenges associated with this approach that are at least partially linked to missing capabilities of current tools (such as [Ora10] and [IBM10]).

First, there is a high chance that even a capable business analyst is not able to identify all improvement levers, especially in complex processes. This is partially due to the fact that BPM tools (and for that matter, most books on optimization, as discussed in [SM08]) offer no guidance as to how to actually change the process to achieve optimal results. Second, as current tools typically fail to provide data integration capabilities, the analysis does not take into account all relevant data sources [RML08]. This might mean that some improvement opportunities are missed, since they can't be inferred from a single data source. Third, during the design and execution stage, optimization decisions typically rely on either static models or artificially generated data from simulation. Hence, experiences and improvements already made in existing processes might not be applied to new processes. Finally, since analysts have to "find" all the improvement areas themselves, the analysis requires significant time and resources. This incurs both costs for the analysis itself and opportunity costs due to delays in the implementation of the optimized process [Hac02].

To address these challenges, a *deep*[1] *Business Optimization Platform (dBOP)* is required, that supports optimization within BPM during process design, execution and analysis. Figure 1 gives a brief comparison of this approach to "traditional" optimization approaches.

In this paper, we first sketch the architecture and the requirements for such a platform (Section 2). Then, we move on to provide the details about the analysis stage of the optimization cycle: in Section 3, we discuss methods and techniques used for integrating and analyzing the data pertaining to the process. Next, we take an in-depth view in Section 4 on how the actual process optimization is conducted during the analysis stage. In Section 5 we discuss this paper in the context of related work before providing the conclusion and the outlook on future work in Section 6.

2 The Deep Business Optimization Platform

In this section, we first provide a business scenario that is used as a guiding example for the *dBOP* and as an example throughout the paper. Then we briefly show how *dBOP* supports all three optimization stages before we take a closer look at the analysis stage.

2.1 Guiding Example

Throughout the paper, we use the sales process of the *Car Rental Company Ltd.* as schematically shown in Figure 2 as our example.

The company is using BPEL to orchestrate the process and data flow between its backend systems. Now, that the focus of the company's optimization efforts starts to shift towards

[1] Note that throughout the paper, the term "deep" refers to the fact that we base our optimization on an integrated view of all operational data (i.e., data that is generated by some application, such as an ERP system, outside the processs engine itself) and process data that pertains to the process. In contrast to optimization approaches relying exclusively on (actual or simulated) process data, this enables us to find a broader range of optimization levers.

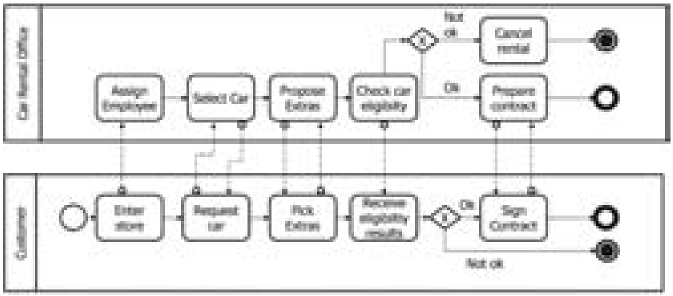


Figure 2: Schematic Car Rental sales process in BPMN

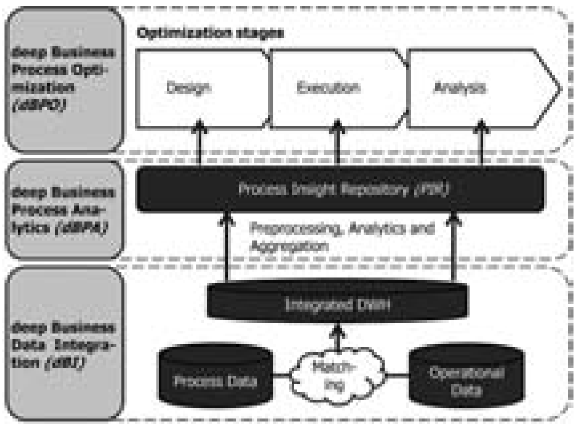


Figure 3: *deep Business Optimization Platform* overview

entire business processes, there are some challenges that cannot be adequately addressed by either the company's Data Warehouse or the process data of the BPEL engine employed.

Fueled by above-benchmark process durations and costs, the company suspects that there are problems in the process flow as well as the staff allocation during the process execution. Further*Car Rental Company Ltd.* is considering moving into a new business, that is, the rental of motorcycles. For that purpose, they have designed a new sales process. Now, they would like to leverage experiences from their car rental process, but so far have not been able to link the two.

In the remainder of this paper, we show how our approach helps to address these challenges, with a specific focus on the process analysis.

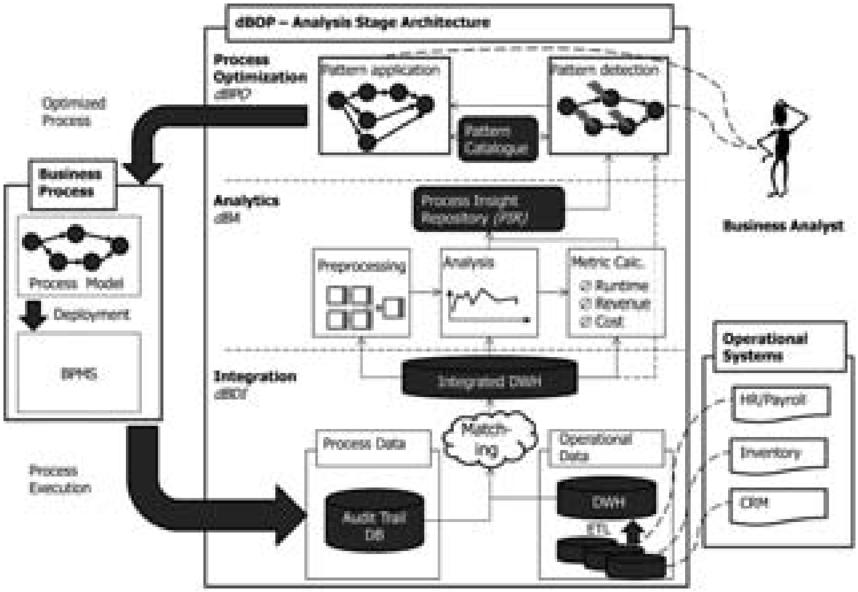


Figure 4: Overview of the *dBOP* analysis stage architecture

2.2 Platform capabilities and architecture

As Figure 3 shows, the *dBOP* is made up of three main architectural layers: The *deep Business Data Integration (dBDI)* layer matches heterogeneous data sources so that the process analysis can extend to all relevant data (for details, see Section 3.1). Building on this integrated data, the *deep Business Analytics (dBA)* layer extracts process optimization-relevant "insights" (see Section 3.2). The results are stored in the *Process Insight Repository (PIR)*. Finally, the *deep Business Process Optimization (dBPO)* layer conducts the actual process optimization based on insights from the *PIR*. The mode, steps and prerequisites of the *dBPO* depend on the stage (design, execution or analysis) during which the optimization is conducted. The focus of this paper is on the analysis stage, in which the *dBPO* uses existing execution data to determine the most feasible optimizations. During the design stage, a similar approach is employed after prior process matching (see [NRM10] for details). During the execution stage, we use the *PIR* to dynamically solve decision and selection problems, e.g., by allowing for attribute-based instead of role-based resource allocation.

2.3 Analysis stage architecture overview

As mentioned before, the focus of this paper is on the analysis stage of the *dBOP*. This is why in this section, we briefly introduce the *dBOP* analysis stage components that provide an implementation of the concepts discussed in Section 2.2.

The analysis stage architecture as shown in Figure 4 consists of three main components:

1. It provides a uniform view on all relevant data pertaining to the process through the *dBDI* layer. This includes process and operational data, as well as the process model (Section 3.1).
2. Building on the results of *dBDI*, optimization-focused insights are generated and stored in the *PIR* using the preprocessing and analytics techniques that are part of the *dBA* layer (Section 3.2).
3. Leveraging the insights gained by integrating and analyzing the process data, the *dBPO* layer is tasked with performing the actual optimization. For that purpose it uses a set of "optimization patterns" stored in the *Pattern Catalogue* that help analysts with detecting and addressing deficiencies in the process (Section 4).

3 Deep Business Data Integration and Analysis

This section introduces the methods and technologies used for the integration and the analysis of the process-relevant data. Both the integration and the analysis layers are necessary in order to provide the optimization with the required insights.

3.1 Deep Business Data Integration

As discussed in Section 2.3, the goal of the *dBDI* layer is to provide a standardized, uniform way of accessing process and operational data together. Since this layer has been discussed intensively (e.g., [RML08] and [RM09]) and implemented (see for instance [RNB10]) in our previous work, we only give a brief overview of the steps required:

1. **Annotation and matching of the process and operational data models:** As the first step of the *dBDI* layer, we need to integrate the data models of the process data and the operational data. For that purpose, we have developed a matching method and an editor that allows for manual, annotation-based/semi-automatic and automatic matching of the data models.
2. **Audit data standardization and mapping the integrated data model to the instance data:** Since the audit data generated during the process execution is typically stored in proprietary format, some standardization of the data is necessary in order to allow for integration with a number of different platforms. To achieve this task, we use a tailored version of the Business Process Analytics Format (BPAF), a standard published in [WfM09]. This step further includes transferring the matching of the operational and process data models to their concrete instances.

Figure 5: Data preprocessing for the Deep Business Analysis

3.2 Deep Business Analytics

In Section 2, we have already briefly presented the *dBA* layer. The goal of this layer is to provide a concise view on the aspects of the process (such as activity execution times, waiting times, relevant process attributes) that might be relevant for optimization. To achieve this goal, several Data Mining techniques and algorithms are adopted to the specific requirements of integrated process and operational data. First, however, the data needs to preprocessed to provide an optimal input for the analysis algorithms [HK06].

3.2.1 Data preprocessing

Since the field of data preprocessing is already covered extensively in Data Mining literature and research [KKP06], we discuss only the specifics of our data preprocessing approach shown in Figure 5:

1. **Leverage of semantics in the preprocessing of attributes:** A central element of our approach to data integration (see Section 3.1) is the semantic annotation of both the operational and the process data. This annotation is used as domain knowledge during preprocessing, e.g., to cluster types of cars or car rentals.

2. **Preprocessing of process activities and other process elements:** To reduce dimensionality, we remove process elements from the Data Mining input that are not result-relevant (e.g., have no influence on the process result or its execution time)

3. **Statistical data preprocessing:** After the specific steps mentioned above have been concluded, standard (mainly statistical) preprocessing steps such as data cleaning and data normalization are applied.

3.2.2 Conducting the analysis

The key step of the *dBA* is the application of Data Mining algorithms to the integrated, preprocessed data in order to extract the insights required for the optimization. For this purpose, techniques and algorithms from several of the areas listed in [HK06] are used and adapted (see [RM09]). The techniques most widely used are:

- **Concept and class description**, mainly through the calculation of key process metrics such as minimum, maximum, average and median activity duration.

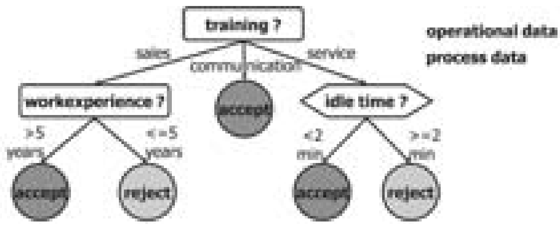


Figure 6: "Predict Flow" pattern: sample usage of classification trees [RM09]

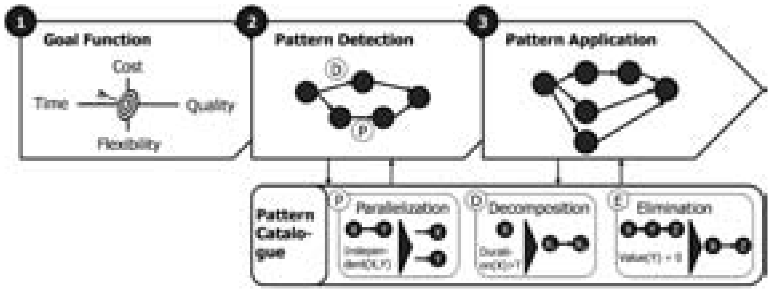


Figure 7: The optimization process

- **Mining frequent patterns**, associations and correlation by association rule mining and multiple linear regressions. This is used to determine the factors that influence process and activity outcomes most. This is e.g. used for the "Resource Allocation" pattern, where Data Mining is used to determine the "optimal" resource (e.g., the best possible salesman in the Car Rental example) to be used for a certain task. For more information on optimization patterns, see Section 4.2.
- **Classification and prediction** to predict the class label of objects, e.g. by classification trees and neural networks. This can be used to predict the further flow of the process at any given time, as is, e.g., required for the "Predict Flow" pattern shown in Figure 6.

4 Deep Business Process Optimization

After the analysis of the process and the operational data has been concluded, all the prerequisites for conducting the process optimization are fulfilled. Now, the business analyst can use the *dBPO* to (semi-)automatically detect and apply a set of optimization patterns.

4.1 Optimization methodology

As Figure 7 shows, the optimization methodology consists of three main steps:

1. **Goal function definition:** Most organizations do not have a single goal, but rather have to work in a complex goal system (e.g., cost, quality, revenue, flexibility) together with associated constraints (e.g., utilization needs to be kept below x%). Hence, the analyst first has to pick the optimization goal as well as any constraints that should be considered during the optimization.

2. **Pattern detection:** Identification of potential optimizations and interaction with the business analyst as to if and how to apply them.

3. **Pattern application:** Rewriting of the process to implement the desired optimizations, including any manual process modifications done by the business analyst.

After the optimization process has been concluded, the new, optimized process model is returned.

4.2 Optimization patterns

In this section, we briefly discuss the basic foundations of optimization patterns and the *Pattern Catalogue* before moving on to a concrete example, the "Automated Approval" pattern.

4.2.1 Foundations

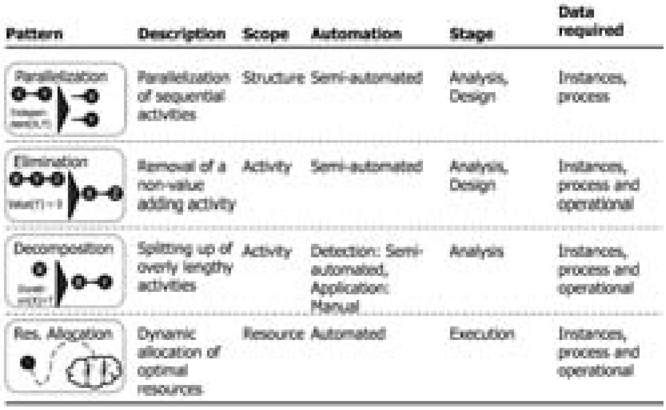
Process optimization patterns are a formalization of (typically verbally described) "best practice" techniques for the optimization of processes (as found for instance in [Rei05]) with respect to one or several goal functions. A pattern consists of a detection and an application component.

The detection components is made up by a(formal) description of the process structure and the analysis results that indicate that the application of the pattern might be beneficial. The application component is the specification of the transformation logic that is required to achieve the desired optimization.

The key to a successful application of the pattern is a high degree of automation and formalization. For this reason, the patterns need to be described in formal language that shifts as much work as possible from the business analyst to the optimizer.

4.2.2 Pattern Catalogue

The core of the *dBPO* layer is formed by the *Pattern Catalogue* that prescribes both the pattern detection and application approach for the available optimization patterns.



Pattern	Description	Scope	Automation	Stage	Data required
Parallelization	Parallelization of sequential activities	Structure	Semi-automated	Analysis, Design	Instances, process
Elimination	Removal of a non-value adding activity	Activity	Semi-automated	Analysis, Design	Instances, process and operational
Decomposition	Splitting up of overly lengthy activities	Activity	Detection: Semi-automated, Application: Manual	Analysis	Instances, process and operational
Res. Allocation	Dynamic allocation of optimal resources	Resource	Automated	Execution	Instances, process and operational

Figure 8: *Pattern Catalogue* excerpt

Within this catalogue, patterns are distinguished by several different criteria, such as optimization scope (e.g., (sub-)processes or single activities), degree of automation/required analyst input, time of application (design, execution or analysis time) and data requirements.

Based on these criteria and an extensive literature search, we have defined a set of now more than 20 optimization patterns, some of which are shown in Figure 8.

4.2.3 Example application: "Automated Approval" pattern

In this section, we briefly illustrate the optimization process with the "Automated Approval" pattern. This pattern refers to a frequent situation in business processes, where a human actor has to manually approve whether the prerequisites for a certain process step are met (in our example, this would be the approval that the customer is eligible for the desired car). Such an approval is typically associated with significant human involvement which usually equates high costs and long delays. As we want to optimize process time (without further constraints), the optimization pattern is applied as shown in Figure 9

1. The Pattern "Automated Approval" is selected from the *Pattern Catalogue*.

2. The process is scanned for all decisions whose execution, on average, show a significant impact w.r.t. the chosen process goal function (in our case: time/process duration). In this case, the "Check Car Eligibility" activity increases the process duration by 10 minutes on average.

3. A query to the *PIR* is used to find out the process and operational attributes that statistically influence the decision most. In our example, all recurring customers with > 5 rentals or those customers seeking to rent an economy car are nearly always approved.

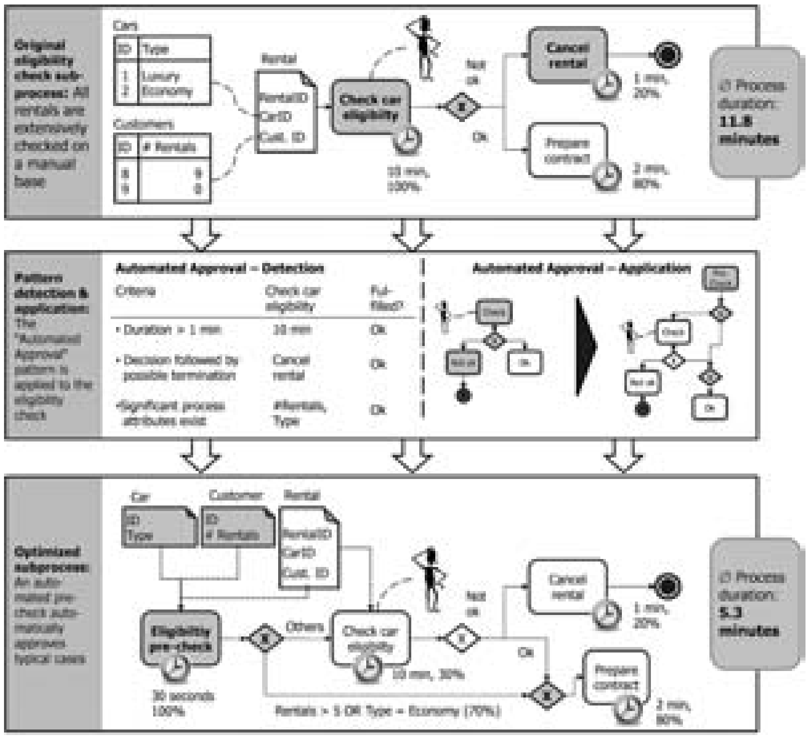


Figure 9: Applying the "Automated Approval" pattern

4. Once these are determined, an (automated) decision is inserted just before the manual decision. Since the automated decision is able to handle 70% of the decisions, the process duration is significantly shortened.

5 Related work

For the discussion of related work, it is helpful to distinguish between work similar to the *dBOP* as a whole and topics related to the tasks of the respective architecture layers.

Looking at the platform as a whole, [CCDS04] take a similar approach in the sense that they are using models similar to our patterns to achieve a higher level of insights when analyzing processes, however, without concrete support for optimization. Other work focuses on providing better optimization and design tools [BKKO06], however, without leveraging execution data.

Considering the integration of heterogeneous data sources as required for the *dBDI*, this is the classical domain of schema matching approaches such as [ADMR05] which, however, sometimes struggle with the specifics of process data. [DH05] explores the possibilities of using semantics for integrating operational data sources, an approach that we have extended to the specific requirements of matching operational and process data. Looking at commercial products, IBM Information Server supports the integration of heterogeneous data sources, however, the process is not well-suited for process data.

With regards to the specialized data processing and analytics required for the *dBA*, this can be seen as an application of Business Process Analytics [zMS09]. However, this rather new area has in many cases not reached the maturity necessary to provide actual algorithms to be used during the analysis. We hence leverage classical Data Mining [HK06] and data preprocessing approaches [KKP06] and custom-tailor them to the specifics of process data, such as high dimensionality or specific optimization goals.

The optimization itself has so far been considered a task that has to be done largely manually by the business analyst. Hence, related work typically focuses on describing the basic concepts and benefits of business process optimization/reengineering such as [Cha95] or [HC93], providing guidance for the optimization process [SM08] or discussing single optimization techniques [Rei05] (exceptions to this pattern, such as [VdA01] are typically restricted to single, highly specific process types). Looking at the tool landscape, applications such as [IBM10] typically focus on providing somewhat processed information about actual or expected process behavior (i.e., simulation), however, without guidance as to how to apply it to a concrete process optimization.

Overall, the approach of a system that automatically adapts according to feedback from its execution can be conceptually seen as an application of cybernetics [Wie48] to BPM.

6 Conclusion and future work

This paper demonstrated that current, largely manual process optimization techniques based on non-integrated data present a significant obstacle on the way to achieving superior business process performance. Our *dBOP* platform helps to address this challenge by providing an environment for the (semi-) automated optimization of processes:

- The *dBOP* integrates process and operational data, as well as any other required data source. Hence, our analysis of the process is able to uncover "deep" insights that are not readily visible when looking at single data sources.
- Instead of just querying the process database, we use customized Data Mining techniques and algorithms to extract insights from the data available to us. Instead of just looking at the exhibited process behavior (*What* is happening?), we are able to examine the factors that might be causal for certain behaviors (*Why* is it happening?).
- Through the pattern catalogue, aan analyst using the platform is not just presented with information, but also given concrete guidance as to how to use it to improve the process and increase business value. Hence, the platform presented in this paper allows for a fast and cost-efficient process optimization that ensures high process quality while taking into account different business goals and constraints.

In our future work, we will refine the algorithms and tools used by the *dBOP*. Further, we will extend our approach to the design and execution stages as outlined in Section 2.2 and conduct a thorough empirical validation of the various aspects of the platform.

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Optimizing Semantic Web services ranking using parallelization and rank aggregation techniques

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Abstract: The problem of combining many rank orderings of the same set of candidates, also known as the rank aggregation problem, has been intensively investigated in the context of Web (e.g meta-search) databases (e.g combining results from multiple databases), statistics (e.g. correlations), and last but not least sports and elections competitions. In this paper we investigate the use of rank aggregation in the context of Semantic Web services. More precisely we propose an optimization technique for ranking Semantic Web services based on non-functional properties by using parallelization and rank aggregation methods. Instead of using a ranking algorithm over the entire set of non-functional properties our approach splits the set of non-functional properties in multiple subsets, runs the ranking algorithm on each of the subsets and finally aggregates the resulting ranked lists of services into one unifying ranked list. Experimental results reported in this paper show improvements of our initial rank aggregation method both in terms of quality and processing time.

1 Introduction

Two of the most important challenges in any service-oriented infrastructure are how to identify the relevant services given a user request and how to provide an ordered list of services according to user preferences. Known as service ranking, the later challenge has been investigated both by academia and industry ([26], [15], [19]).

Existing approaches for service ranking provide in general one single rank ordering given a set of services and a user request. Based on the same input data (same user request and services) different ranking engines create different rank lists. This is due to specific algorithms employed by each of the ranking engines, different ways of interpreting the request and service descriptions, etc. In the future service-oriented ecosystems, ranking engines become service themselves that produce different rank lists given the same user request. One challenge that becomes important in this context is how to identify the best rank list out of a given set of rank lists produced by different ranking engines. This is a difficult task and in most cases difficult to achieve due to the lack of access to the inner mechanics of the individual ranking engines.

A consensus mechanism that combines the rank lists produces by individual rank engines into a communally agreed rank list is more likely to create the 'optimal' solution. Building such a consensus is equivalent to solving the *rank aggregation* problem. This problem can be defined more formally as follows. Given a set of rank lists R_1,...,R_m, each of them the rank lists of the set S of services $S = \{s_1, s_2, ..., s_n\}$, the problem is to identify the 'optimal' rank list σ such that $\sum_{k=1}^{m} D(\sigma, R_k)$ is minimized, where D is a distance metric showing how much two rank lists are similar respectively different.

The rank aggregation problem has been studied in the context of many fields such as social choice theory ([10], [27]), statistics ([5], [4]), machine learning ([13], [14]), web search engines ([7], [21]),sports and competitions ([11], [24]). To the best of out knowledge the rank aggregation problem has not been investigated in the context of finding consensus among Semantic Web services rank engines.

Semantic Web services [8] are a new paradigm that combines on one hand the *Semantic Web* [9] vision, as the augmentation of the current Web supporting meaningful retrieval of data and interaction in a precise, semantically defined way, and on the other hand *Web services*,as the technology that brings the aspect of dynamic and distributed computation into the current Web. Semantic Web services provide increasing degree of automation with respect to all service related tasks, including discovery, composition, execution and last but not least, *ranking*. Among the properties of services in general, and Semantic Web services in particular, *non-functional properties* are considered to be the most relevant properties for the task of ranking services and identifying the best service given a user request. They describe restrictions over the other properties of the services [2] including functional and behavioural properties.

In this paper we investigate the use of rank aggregation in the context of Semantic Web services. More precisely we propose an optimization technique for ranking Semantic Web services based on non-functional properties by using rank aggregation methods. Instead of using a ranking algorithm that consider the entire set of non-functional properties requested by the user, our approach splits the set of non-functional properties in multiple subsets, runs the ranking algorithm on each of the subsets and finally aggregates the resulting rank lists of services into one unifying rank list.

The rest of the paper is organized as follows. Section 2 introduces some basic concepts used latter on in the paper. A set of rank aggregation methods that have proved to be efficient in other domains (i.e. Web) are described in Section 3. Section 4 discusses our ranking algorithm for Semantic Web services based on non-functional properties. Taking the rank aggregation methods introduced in Section 3, Section 5 proposes optimization techniques for the ranking algorithm introduced in Section 4. Section 6 presents the experimental results obtained for rank aggregation with Semantic Web services. Section 7 discussed related work approaches for the problem of rank aggregation and finally Section 8 concludes the paper and presents our future work.

2 Background

Before we describe our approach for rank aggregation of Semantic Web services we introduce the terminology used in this paper.

Let U be a universe of services, S a subset of U, and $\leq_O$ a partial order relation on S. We define a rank list as an ordering of S on which the partial order relation $\leq_O$ holds over any pair of services. More formally a *rank list* is defined as follows.

[Rank list] Given a set S of services $S = \{s_1, s_2, ..., s_n\}$, a partial order relation $\leq_O$ on this set and a ranking function f, a rank list R can be defined as $R = f(S, \leq_O)$, where R contains all the elements from S and $\exists s$ a sequence $s(1, 2, ..., |R|) \rightarrow R$ such that $\forall i, j \in \{1, 2, ..., |R|\}$, with $i <= j \Rightarrow s(i) \leq_O s(j)$.

In case R contains all the elements from the universe U, R is called a *full rank list*. If only some of the elements of U are ranked, R is call a *partial rank list*.

A *ranking metric* or *ranking distance* is a function that computes the similarity between two rank lists, where the similarity is a positive real number. A ranking metric is defined as follows.

[Ranking Metric] Given two rank lists R_1 and R_2, a ranking metric Δ or distance between the two rank lists is defined as a function $\Delta : \mathcal{R} \times \mathcal{R} \rightarrow \mathbb{R}^+$ that determine the degree of similarity between the two rank lists.

Any *ranking metric* has the following properties: (1) it is *non-negative*, meaning that the distance between two rank lists is always positive, (2) is it *identical*, meaning that if distance between two rank lists is 0 then the two rank lists are the same, (3) it is *symmetric*, meaning that the given two rank lists R_1 and R_2, the distance between R_1 and R_2 is the same as the distance between R_2 and R_1 and finally (4) it preserves the *triangle inequality*, meaning that for any three rank lists R_1, R_2 and R_3 any ranking metric Δ will satisfy the following inequality $\Delta(R_1, R_2) \leqslant \Delta(R_1, R_2) + \Delta(R_2, R_3)$

Some of the most used ranking metrics are *Kendall-Tau* [12] and *Spearman Footrule* [23].

Kendall-Tau (Kendall's τ) determines the degree of similarity between two rank lists by considering the number of inversions of pairs items needed to transform one rank list into the other. It basically corresponds to the number of transpositions *bubble sort* requires to turn one rank list into the other one. The Kendall's τ ranking metric is defined as follows:

$$\tau = 1 - \frac{2\delta}{N(N-1)} \tag{1}$$

where δ is the *symmetric difference distance* between the rank lists created based on the given sets of items and N is the total number of items. The symmetric difference distance is a set operation which associates to the rank lists, the set of elements which belong to rank lists. The Kendall's τ ranking metric value for two lists of length n can be computed in $nlogn$ time [7].

Spearman Footrule (Spearman's ρ) captures how well an arbitrary monotonic function could describe the relationship between two variables, without making any assumptions about the frequency distribution of the variables. The Spearman ranking metric is defined as follows:

$$\rho = 1 - 6\frac{\sum_{i=1}^{N} d_i^2}{N(N^2-1)} \tag{2}$$

where d_i is the difference in statistical rank of corresponding variables, and N is the number of pairs of values. Equation 2 can be rewritten in the following form:

$$\rho(X,Y) = \frac{\sum_{i=1}^{N} x_i y_i}{\sqrt{\sum_{i=1}^{N} x_i^2 \sum_{i=1}^{N} y_i^2}} \tag{3}$$

The Spearman Footrule metric between two lists can be computed in a linear time.

3 Rank aggregation methods

In this section we present the rank aggregation methods that are used to optimize our existing ranking approach for Semantic Web services based on non-functional properties [25].

Borda count method The Borda count [1] is a rank aggregation method that computes the aggregated rank list based on the cumulative positional score obtained by each candidate in each rank list. The candidate with the highest score is the winner, followed by the other candidates in decreasing order of their scores. More formally the Borda count method works as follows. Given the full rank lists $R_1, R_2, ..., R_n$ of a set of services S, then for each candidate $s \in S$, Borda count method assign a score $B_i(s)$ equal to the number of the candidate services that are ranked lower then s in the rank list R_i. The cumulative score for the candidate s is:

$$B(s) = \sum_{i=1}^{n} B_i(s) \tag{4}$$

An important advantage of *Borda count* method and of other positional rank aggregation methods is that they are computationally very easy as they can be implemented in linear time. However such methods, including Borda count method, do not satisfy the Condorcet criterion [27], namely if the Condorcet winner exists is not guaranteed that it will be selected by the voting system. The Condorcet winner is that candidate that defeats any of the other candidates in two-candidates election.

Markov chains based methods In [7] a set of four methods based on Markov chains have been introduced to solve the problem of rank aggregation. A Markov chain [18] is a stochastic process consisting of a domain D, a set of states $\{s_1, ..., s_m\}$, an *initial distribution vector* $(p(s_1), ..., p(s_m))$ and a mxm *transition probability matrix*, where m is the total number of states. In a Markov chain the present state of the system captures all the information that could influence the future evaluation of the system (past states do not influence future states). The system moves from one state s_i to another state s_j with a probability P_{ij}. Rank aggregation methods based on Markov chains try to compute the stationary distribution of the Markov chain which represents the resulting rank aggregation list.

The Markov chains based methods proposed in [7] are using different heuristics rules to construct the transition probability matrix. In [7] the states are basically the web pages rank by rank engines, while in our case services represent states of a Markov chain. Given a service S_i, representing a current given state of the system, the four heuristics introduced in [7], denoted shortly by MC1, MC2, MC3 and MC4 are informally defined as follows:

- **MC1**: Choose uniformly from the multiset of all candidate services that were ranked at least as high as S_i in a rank list R.
- **MC2**: Choose a rank list R uniformly at random and pick uniformly at random from among the candidate services that were ranked at least as high as S_i in R.
- **MC3**: Choose a rank list R uniformly at random and pick uniformly at random a service S_j. If service S_j was ranked higher then current state (service S_i) in the rank list R, then select S_j as current state, otherwise stay in S_i.
- **MC4**: Choose a candidate service S_j at random. If S_j was ranked higher than S_i in most rank lists then choose S_j as current state, otherwise stay in S_i.

As pointed out in [7], method MC4 outperforms the other methods as well as the Borda count methods. We investigate all the methods introduced above on a Semantic Web services dataset and we report results in Section 6.

4 Describing and ranking Semantic Web services

This section briefly introduces our approach for modeling non-functional properties of Semantic Web services and the ranking algorithm we used for ranking services based on non-functional properties. As a model framework and language to semantically describe services we use the Web Service Modeling Ontology (WSMO) [22], respectively the Web Modeling Language (WSML) [3]. WSMO/L is a comprehensive approach for modeling Semantic Web services that offers complete rule-based modeling support required in our scenarios.

Non-functional properties of services are modeled by means of logical rules in which the terminology (e.g. concepts, relations) is provided by a set of non-functional properties ontologies [1]. Listing 4 displays a concrete example on how to describe the *obligations* non-functional property of a service.

```
namespace {_"WS1.wsml#",
   so _"Shipment.wsml#",
   wsml _"http://www.wsmo.org/wsml/wsml−syntax/"}

webService ws1Service
  nonFunctionalProperty deliveryTime hasValue ?deliveryTime
    definedBy
    //delivery time per order/package depends on dimension of the package; WS1 deliveryTime are as follows:
    // 1 day if volume <= 20 cm3, 3 days if volume > 20 cm3
    computeDeliveryTime(?package, ?deliveryTime):? ?package[so#length hasValue ?length, so#width hasValue ?
          width,
      so#height hasValue ?height] memberOf so#Package and ?volume = (?length ? ?width ? ?height) and ?
            volume < 20 and ?deliveryTime = 1.
    computeDeliveryTime(?package, ?deliveryTime):? ?package[so#length hasValue ?length, so#width hasValue ?
          width,
      so#height hasValue ?height] memberOf so#Package and ?volume = (?length ? ?width ? ?height) and ?
            volume = 20 and ?deliveryTime = 1.
    computeDeliveryTime(?package, ?deliveryTime):? ?package[so#length hasValue ?length, so#width hasValue ?
          width,
      so#height hasValue ?height] memberOf so#Package and ?volume = (?length ? ?width ? ?height) and ?
            volume > 20 and ?deliveryTime = 3.
```

Listing 1: WS1 obligations

More informally the service delivery time is as follows: in case the volume of the package is lower or equal than $20cm^3$ then the delivery time is one day, otherwise if the volume of the package is more than $20cm^3$ the delivery time is three days.

The ranking algorithm that consider multiple non-functional properties of Semantic Web services such as the one presented in the previous example was introduced as part of our previous work [25]. In rest of this section we shortly recap how the algorithm is working. A particularity of our ranking algorithm is the evaluation of the logical rules used to model non-functional properties of services by a reasoning engine. In a nutshell the multi-criteria ranking algorithm works as follows. First the non-functional properties the user is interested and their importance are extracted from the user goal description. The importance of a non-functional property is an number between 0 and 1, 0 denoting no user interest on that property, 1 denoting maximum user interest. Each service from the available set of services in the repository is checked if its description contains the non-functional properties specified in the user goal. If this is the case the corresponding logic rules are extracted and evaluated using a reasoning engine which support WSML rules. A matrix containing the services, as first dimension, and the set of non-functional properties the user is interested, as the second dimension, is constructed. The elements of this matrix are the non-functional properties values of each service obtain during the previous rule evaluation step. The matrix values are normalized and a aggregated score is computed for each service taking into account the importance of the non-functional properties. Finally the scores values are sorted and the final list of services is returned. For more details we refer the reader to our previous work [25].

[1] www.wsmo.org/ontologies/nfp

5 An approach for Semantic Web service ranking optimization

Having introduced our ranking approach for Semantic Web services (Section 4) and a set of general rank aggregation methods (Section 3), this section proposes an an optimization of the initial ranking approach for Semantic Web services by use of parallel processing and rank aggregation methods. The experimental results (Section 6) show considerable improvements in terms of *processing time* and *quality* of results.

The first step of the optimized approach is to split the set of non-functional properties requested by the user into multiple subsets. If $[NFP_1, NFP_2, ..., NFP_n]$ is the full set of non-functional properties the user is interested, the resulting subsets are of form $\Lambda_k = [NFP_1^k, ..., NFP_{|\Lambda_k|}^k]$, k is the total number of subsets. A non-functional property will be part of only one subset. More formally if $NFP \in \Lambda_k$ then $NFP \notin \Lambda_j$, where $j \neq k$. In our experiments the subsets of non-functional properties Λ, have the same cardinality.

As described in Section 4, the initial ranking algorithm constructs a matrix containing the services, as one dimension, and the set of non-functional properties the user is interested, as the other dimension. The elements of this matrix are the non-functional properties values of each service that are computed by evaluating the logical expressions (logic rules) representing the non-functional properties. Splitting the set of non-functional properties requested by the user into multiple subsets results in splitting the services/non-functional properties matrix, as exemplified in Figure 1.

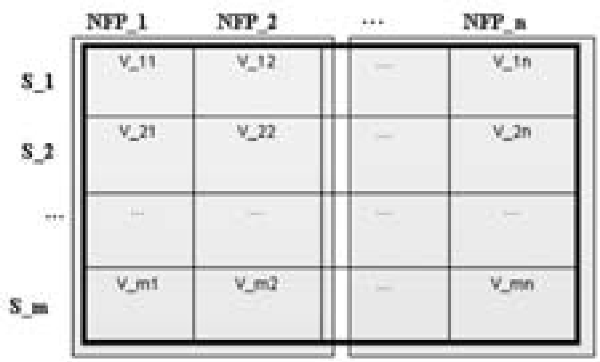

Abbildung 1: Optimization approach.

The second step is to apply the ranking algorithm described in Section 4 on each subset of non-functional properties. The ranking algorithm is applied in parallel to subsets Λ of the initial set of non-functional properties. The initial pre-processing part, including the extraction of user preferences from the goal as well as the extraction of non-functional properties descriptions from the services is performed at once for all the multiple instances of the algorithm. The evaluation of the logical expression representing the non-functional properties is done in parallel which reduces the processing time. It is known that the use of a reasoner on big data set is a time consuming task. The following steps of the initial ranking algorithm are followed for each of the subsets. This includes the normalization of the values obtained, the computation of each service score by aggregating its corresponding non-functional properties values from the given subset and finally the ordering of the services based on their scores. A rank list of services is obtained for each of the subsets of the non-functional properties set requested by the user.

The third and final step of the overall optimized Semantic Web service ranking solution includes the use of rank aggregation methods to aggregate the rank lists of services obtained as the result of the previous step. Figure 2 depicts the last step of the approach.

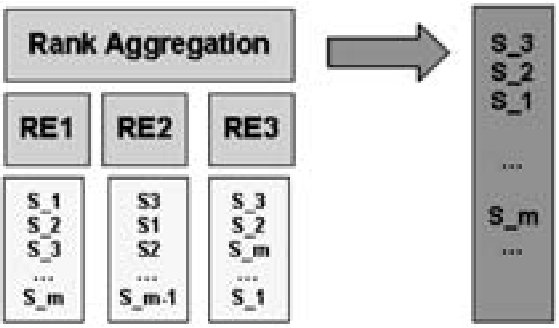

Abbildung 2: High level overview of aggregation.

Each instance of the initial ranking algorithm, depicted in the figure as RE_{Λ_i}, produces a rank list R_{Λ_i}. The rank lists are finally aggregated using rank aggregation methods introduced in Section 3.

6 Experiments, results and discussions

In this section we report the results obtained by applying first the initial, non-optimized method for ranking Semantic Web services and second a set of rank aggregation methods as part of the optimized approach.

6.1 Data set and experimental setup

In our experiment we use a set of 50 Semantic Web services each having 4 non-functional properties descriptions. The non-functional properties that we consider are: *price and discounts*, *obligations*, *delivery time* and *rewards*. *Price and discounts* represent the price charged by the shipping service to ship a package from one place to another. On top of it some shipping services might provide discounts if certain conditions are fulfilled. As obligations we model any payment obligations of the enterprise providing the shipping service in case the package to be delivered is lost or destroyed. The *delivery time* is simply the required time expected by the provider to deliver the package. Finally as *rewards* we modeled reward points that shipping service might offer to their customers.

The set of Semantic Web services used in our experiments was modeled starting from concrete shipment services descriptions. The WSDLs of these services were provided to us by seekda[2]. The set includes as well the 5 shipment services from the SWS Challenge Shipment Discovery scenario[3]. The initial WS Challenge Shipment Discovery scenario have been extended the by augmenting services description with the previously mentioned 4 non-functional properties. Similarly non-functional properties of WSDL services from the seekda collection are semantically described using the WSMO approach.

6.2 Results

Table 1 contains the average execution times in milliseconds for the initial ranking algorithm and the five rank aggregation methods (i.e., Borda, MC1, MC2, MC3 and MC4). For each algorithm/method, the execution time reported is the arithmetic mean of the execution times of 10 trials. For each of the five rank aggregation methods we consider two cases, one in which two ranking lists are being aggregated and the second in which three ranking lists are being aggregated. The user request used in all cases is the WSML goal that corresponds to informal query: "Rank the services based on the combination of price/discounts, liability/obligations, delivery time and rewards, where price/discounts and liability/obligations are equally important, delivery time and rewards are equally important but the first two are more important than the second two. The results must be in descending order."

The resulting execution times are available in Table 1.

	1 ranking list (in millisec)	2 ranking lists (in millisec)	3 ranking lists (in millisec)
Initial	197362	-	-
Borda	-	155248	145915
MC1	-	155642	145883
MC2	-	153344	144757
MC3	-	153735	145612
MC4	-	154889	144738

Tabelle 1: Ranking framework - Average execution times.

As reported in Table 1, the optimized approached based on parallelization and rank aggregation techniques performs better in terms of execution time than the initial ranking approach. Besides execution time our evaluation focuses also on qualitative performance. The qualitative performance results for each method is quantified based on the ranking metrics defined in Section .

Table 2 contains the Kendall's τ correlation values between the ranking lists results generated using the optimized approaches and the reference ranking list for Query Q_5.

Table 3 contains the Spearman's ρ correlation values between the ranking lists results

[2]seekda.com

[3] http://sws-challenge.org/wiki/index.php/Scenario:_Shipment_Discovery

	1	2	3
Initial	τ=0.81	-	-
Borda	-	τ=0.87	τ=0.81
MC1	-	τ=0.82	τ=0.80
MC2	-	τ=0.73	τ=0.76
MC3	-	τ=0.79	τ=0.73
MC4	-	τ=0.92	τ=0.81

Tabelle 2: Ranking framework - Qualitative performance Kendall's τ.

generated using the optimized approaches and the reference ranking list for Query Q_5.

	1	2	3
Initial	ρ=0.95	-	-
Borda	-	ρ=0.92	ρ=0.90
MC1	-	ρ=0.86	ρ=0.84
MC2	-	ρ=0.88	ρ=0.91
MC3	-	ρ=0.90	ρ=0.88
MC4	-	ρ=0.98	ρ=0.93

Tabelle 3: Ranking framework - Qualitative performance Spearman's ρ.

6.3 Discussions

The execution times available in Table 1 show that the rank aggregation methods perform better than the initial ranking algorithm. The percent of improvement ranges between 21% to 26%. One can observe a gradual improvement of the results by splitting the set of non-functional properties further. Rank aggregation methods applied on three ranking lists performs better than the rank aggregation methods applied on two ranking lists, where each list is determined by one or two of the four non-functional properties mentioned before.

For the qualitative evaluation we use two ranking metrics, namely Kendall's τ and Spearman's ρ to measure the quality of each approach. More precisely, we measure the distance between the ranking lists produced by the ranking approaches and the reference rank list created by human experts. A Kendall's τ and a Spearman's ρ value closer to 1 indicates that the ranking list produced by the methods and the reference rank list are highly correlated and thus the method performs well. By contrast, a Kendall's τ and a Spearman's ρ value closer to -1 indicates a higher disagreement between the two lists. One can notice that the approaches based on rank aggregation methods perform in general better than the initial approach. Among the rank aggregation methods, the MC4 method produces the best results.

7 Related work

To the best of our knowledge *rank aggregation* has not been investigated in the context of aggregating rank lists of Semantic Web services nor rank lists of Web services. However, the rank aggregation problem has been studied in the context of social choice theory, statistics, machine learning, web search engines as well as sports and competitions. The pioneering work for developing rank aggregation methods was motivated by challenges from the social theory. One of the most common rank aggregation developed in this context is Borda count [1], shortly described in Section 3. In short the method orders the candidates with respect to the average rank. In [7], rank aggregation methods were discussed in the context of the Web. The rank aggregation called *Kemeny optimal aggregation* is introduced as the optimal rank aggregation solution which optimizes the Kendall distance [12]. In [6], the same authors provide a detailed theoretical analysis of various rank aggregation methods showing that the *Kemeny optimal aggregation* is a NP-hard problem. The authors propose a set of methods based on Markov chains are proposed that approximate the Kemeny optimal. In [16] user preferences are expressed by means of ontologies and rank aggregation methods are used to combine rank lists from various attributes of user preferences when searching the Web. A detail comparison of various rank aggregation methods, including Markov chains based methods, is performed in [20] using TREC data. Furthermore the authors of this work distinguish between rank based and score based rank aggregation methods. Machine learning techniques have been used to solved the rank aggregation problem using either unsupervised learning (e.g. [14]) or supervised learning(e.g. [17]). However these approaches require good training data which is often not easy to obtain.

8 Conclusions

In this paper we have developed an optimization technique for ranking Semantic Web services using rank aggregation techniques. The initial ranking algorithm evaluates the non-functional properties specifications of each service and computes an aggregated score. Our optimized approach uses a parallel version of the initial ranking algorithm and as a last step applies rank aggregation methods to create the final aggregated rank list. We have proposed and test several rank aggregation methods including Borda count and Markov chain based methods. As future work we plan to investigate other rank aggregation methods in the context of rank aggregation for Semantic web services, including both rank and score based methods. We plan as well to perform an extended evaluation of our approaches using a larger data set, i.e. more than 50 services, with a larger number of non-functional descriptions. Another related research direction that we plan to investigate is the use of similarity measures when applying rank aggregation methods for Semantic Web services.

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Static Information Flow Analysis of Workflow Models

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Abstract: This paper proposes a framework for the detection of information leaks in workflow descriptions based on static information flow analysis. Despite the correct deployment of access control mechanisms, certain information leaks can persist, thereby undermining the compliance of workflows to policies. The framework put forward in this paper identifies leaks induced by the structure of the workflow. It consists of an adequate meta-model for workflow representation based on Petri nets and corresponding components for the transformation and analysis. A case study illustrates the application of the framework on a concrete workflow in BPEL notation.

1 Introduction

Over 70% of all business processes deployed today rely on business process management systems for their automated execution [WH10]. The central entity here are workflow specifications that model the business process. Despite the steadily growing expenses in tool design for the secure and compliant deployment of workflows, dependability incidents are still soaring [Dif08], as well as the monetary damage they lead to [MAHS10].

A major source of dependability incidents – and in fact non-compliance – in this setting are information leaks [BKN$^+$09]. Even if correct access control mechanisms and corresponding policies are in place, these leaks undermine the confidentiality of data items and workflow characteristics meant to remain secret. The technical issue here is that access control mechanisms only monitor a particular transmission channel between a classified and a public subject, whereas so-called "covert-channels" are neglected, i.e. channels that are not meant to transfer information but are misused to do so [Lam73].

This paper proposes a framework for the detection of information leaks in workflow descriptions based on static information flow analysis. Information flow (IF) control lays down the basis for a semantic specification of security requirements [ML97]. Compared with traditional access control policies, IF properties are stronger because they capture information propagation throughout the system (*end-to-end*) rather than mere data access. Thus, they can capture security violations that lie beyond the scope of access control mechanisms, such as the information leaks that take place over covert-channels.

The analysis of workflow specifications against IF properties is a novel, promising approach to complement access control mechanisms and, thereby, achieve strong security and compliance guarantees [AW09]. The framework put forward in this paper takes a

Petri net representation of the workflow specification (so-called "IF-net") and analyzes the corresponding net against IF properties. The analysis is mechanized and amounts to testing whether a certain state of the net is reached.

Besides outlining the approach and its elementary theoretical underpinnings, the paper illustrates the application of the framework with an example taken from a larger case study. The example shows how a workflow in BPEL notation is verified for instance isolation, i.e. whether there is any information leak between multiple instances of the workflow. For this purpose, the BPEL process is transformed into a rudimentary IFnet that models the interacting instances. The applied verification technique is tailored for the analysis of Petri nets [BG09]. It detects specific covert-channels arising from the structure of the workflow, in particular the competition for shared resources and control-flow.

The paper makes the following contributions:

- It argues for a semantic analysis of workflow descriptions and their behavior in order to provide reliable security guarantees.
- It proposes a framework for the static IF analysis of workflows and outlines its theoretical underpinning and capabilities. In particular, it presents IFnet, a meta-model based on Petri net to represent workflows for IF analysis.
- It demonstrates in a case study the application of the framework for the verification of a BPEL process for information leaks.

Overall, the approach this paper proposes merely detects the existence of a covert-channel and, thus, of a (possibly intentional) information leak. It is worth emphasizing the following two aspects. First, the detected interference does not necessarily imply a violation of a security policy, it merely indicates an IF. While distinguishing between harmful and harmless interferences is out of the scope of this paper, extensions of the framework presented in Section 2 will also address this issue. Second, once a covert-channel is considered "dangerous", countermeasures must be taken to stop the leak or at least reduce its throughput. Since covert-channel elimination is traditionally infeasible and ends up adding more covert-channels [PN92], other mechanisms, such as redundancy and uniform timing delays, must be set in place to control the leak. Future work aims at evaluating existing strategies for covert-channel control.

This paper is structured as follows: Section 2 outlines the framework for information flow control in workflows. Section 3 presents the case study demonstrating the detection of information flow between interacting instances of a BPEL process. Section 4 lists related work and Section 5 concludes the paper.

Preliminaries on information flow analysis. Information flow analysis is a formal approach to computer security to guarantee the absence of data leaks between designated subjects of a system. For this, the subjects which interact with the system (and actions they can perform) are assigned security labels that indicate their clearances. The security labels are arranged in a lattice, which in the simplest case consists of the two labels $High$ and Low with $High \succ Low$ [Den76].

In IF analysis, the criteria for the security of a system is based on the notion of non-interference [GM82], i.e. the absence of "interferences" between the $High$ part of the system and the Low part. Put another way, the actions of $High$ users lead to *no* observable effect on the behavior of Low. Demonstrating this property ensures that the Low part cannot deduce any information on the behavior of $High$. Interferences can happen over various "channels": besides explicit data transmission through message sending or shared storage (dataflow), there is a variety of *covert-channels*. These include, for instance, control flow, timing and termination behavior, or the probability distribution of processed data [SM03]. To formally prove that a system does not allow IF, the relevant aspects of its behavior are modeled and checked for an adequate non-interference property.

2 A Framework for Information Flow Control in Workflows

This section outlines the proposed approach for IF control in automated workflows. Given a workflow specification, e.g. a BPEL or a BPMN model, the first step consists of *translating* this specification into a Petri net representation. IFnet is the target meta-model. Essentially, it is a colored Petri net enriched with annotations to express the security classes for IF analysis. The IFnet model obtained from the translation of a workflow specification is then *annotated* with the corresponding security classes. Subsequently, a static IF analysis is carried out upon the resultant IFnet. The following provides further details on the corresponding steps and indicates where ongoing work is needed. Section 3 shows an instantiation of this framework with existing tool-support.

IFnet. IFnet is based on Petri nets, as these feature formal semantics and various notions of non-interference for Petri net-based systems are available [BG03]. Further, with their flow-oriented graphical notation, being alike with most workflow management systems, Petri nets are suitable for the formal modeling of workflows [LVD09]. However, the majority of approaches in workflow modeling using Petri nets focuses on the control flow, disregarding dataflow and further covert channels, which are crucial for information flow analysis. IFnet integrates and extends existing approaches to build a workflow meta-model to express different aspects of the workflow, such as its dataflow and resource exhaustion. Further, it is planned to integrate also dynamic aspects into IFnet, such as timing behavior and the probability distribution of execution paths. This information is gained from execution log traces and enables the forensic detection of information flows.

Transformation to IFnet. Transformation of workflows specified in common industrial formats (such as BPEL and BPMN) into IFnet is carried out automatically by extending existing mapping functions [LVD09]. For the BPEL case, there are at least two tools which provide a feature-complete mapping of a workflow's control flow to standard Petri nets, namely "BPEL2oWFN" [Loh07] and "WofBPEL" [OVvdA+05]. Building upon these tools, generated Petri nets will be subjected to a second transformation step that produces the correspondent IFnet models.

Annotation of IFnet models. The goal of the annotation component is to label an IFnet model for IF analysis. Different strategies can be taken to do so, depending on the kind of covert-channel which is to be detected. As shown in Section 3, one strategy is to split the net into symmetric parts representing High and Low users. This "splitting" has been very handy while analyzing IFnet for storage channels. In the dataflow setting, a possible strategy is to derive the labeling from the corresponding access control policies for the particular workflow. Further, the framework also allows the user to label the workflow at his/her will, as in traditional IF analysis.

Focusing on the case of security policies for sake of example, the approach is to generate a lattice of security labels, which is arranged according to the data access modalities specified in the policy, and to assign these labels to the corresponding activities and data items of the IFnet model. As an example, consider a policy that denotes that a Subject 1 may read some data item File A, while Subject 2 must not read that file. An annotation function could classify Subject 1 and File A as "High", while Subject 2 would be "Low". This requirement is significantly stronger than the original access control policy, as it rules out any actions taken by Subject 1 that have an observable effect on Subject 2 (and thus might transmit information on File A).

IF analysis. The analysis tool checks an annotated IFnet model for possible interferences between its "higher"-level and "lower"-level parts. For the analysis of dataflows (i.e. the explicit exchange of data items), so-called "propagation graphs" are extracted from the IFnet model which denote the possible data exchange among the involved subjects. The propagation graphs are subsequently traversed to detect illicit dataflows [AW10]. The detection of covert channels is based on different bisimulation-based notions of non-interference which have been formalized for Petri nets [BG03]. In particular, *Bisimulation-based Non-Deducibility on Composition* (BNDC) [FG95] is a suitable property, as it can be efficiently checked through a semi-static analysis (see Section 3).

3 Case Study

To illustrate the idea behind the framework, this section presents a case study for the verification of a BPEL process. To this end, it employs preliminary variants of the described components.

To preserve confidentiality, several compliance requirements, such as HIPAA and Sarbanes-Oxley, demand that workflows with different security clearances are isolated from each other, i.e. there must be no information exchange between instances of corresponding workflows. A well-known example for such a requirement is the Chinese-Wall security model [BN89]. It aims to prevent conflicts of interest in organizations dealing with clients, which are, for instance, direct competitors in the same market.

This case study demonstrates the verification of such an isolation requirement for concurrently running instances of a BPEL workflow. The BPEL workflow is transformed into a preliminary variant of IFnet. The transformation encompasses two steps: first, the BPEL model is mapped to an equivalent Petri net model using an existing transformation tool; second, the resultant Petri net is "unfolded" into an IFnet instance which models concurrently running instances and their access to shared resources. The IFnet model is subse-

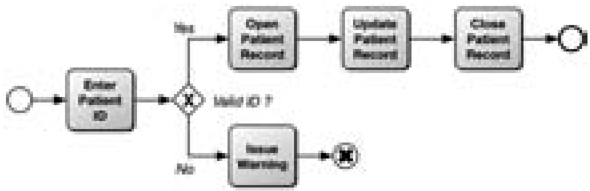

Figure 1: "Update Patient Record" workflow.

quently checked for the BNDC property, which asserts that there can be no information flow from one instance to the other. For the verification, the *Petri Net Security Checker* is used, which implements a checking algorithm for BNDC on Petri nets [FGF08].

Exemplary BPEL Process. The case study uses the "Update Patient Record" workflow depicted in Figure 1, which originates from a project on the automation of business process compliance that was carried out in cooperation with a hospital. Albeit simple, it is a central fragment that recurs in several of the hospital's information systems, e.g. for accounting, medical treatment and insurance billing. It consists of five activities (depicted as boxes) and an exclusive choice (x-diamond) that represents an if-statement. The following fragment shows the corresponding BPEL tags of the workflow.

```
<sequence name="main">
  <empty name="Enter_Patient_ID"/>
  <switch name="Switch_1">
    <case>
      <sequence>
        <empty name="Open_Patient_Record"/>
        <empty name="Update_Patient_Record"/>
        <empty name="Close_Patient_Record"/>
      </sequence>
    </case>
    <otherwise>
      <empty name="Issue_Warning"/>
    </otherwise>
  </switch>
</sequence>
```

The concurrent access to the same patient record causes information leaks. If, for instance, a doctor opens a specific record and blocks an access attempt to the same record by another subject – irrespective of the fact that access control mechanisms are in place –, this subject obtains information on the doctor's behavior: the subject knows that the doctor uses the specific record and might deduce from this fact which patient the doctor is currently treating, as well as the time the doctor needs to update the record.[1] Hence, there would be an IF among workflow instances violating the isolation requirement. The goal of the analysis is to detect these leaks. The following demonstrates how the approach proposed in the previous section achieves this goal.

[1] It is important to note that the patient record in this case holds only administrative information which may legitimately be accessed by all involved parties, i.e. access to the record alone does not constitute an illegal IF.

3.1 Transformation of Workflow Descriptions in IFnet

3.1.1 BPEL to Petri net

The transformation of the initial BPEL process employs the tool "BPEL2oWFN", which implements a feature-complete mapping of BPEL 2.0 to so-called "Open Workflow Nets", a variant of Petri nets tailored to workflow modeling. Some basic definitions of Petri nets are given to facilitate the understanding of the framework.

Petri nets. A Petri net is a tuple $N = (P, T, F)$, where P is a finite set of *places*, T is a finite set of *transitions* such that $P \cap T = \emptyset$, and $F \subseteq (P \times T) \cup (T \times P)$ is a set of directed arcs, called the *flow relation*.

At any time a place contains zero or more *tokens*. The *marking* (or *state*) is the distribution of tokens over places. A marking is a *bag* over the set of places P, i.e. a function from P to the natural numbers: $M \in P \longrightarrow \mathbb{N}$. A partial ordering is defined to compare states. For any two states M_1 and M_2, $M_1 \leq M_2$ *iff* for all $p \in P$: $M_1(p) \leq M_2(p)$. The *sum* of two bags ($M_1 + M_2$) is defined in a straightforward way.

A *marked* Petri net is a pair (N, M), where $N = (P, T, F)$ is a Petri net and M is a bag over P denoting the marking of the net. The set of all marked Petri nets is denoted $\mathcal{N}$.

Let $N = (P, T, F)$ be a Petri net. Elements of $P \cup T$ are called *nodes*. A node x is an *input node* of another node y *iff* there is a directed arc from x to y (i.e. xFy). Node x is an *output node* of y *iff* yFx. For any $x \in P \cup T$, $\overset{N}{\bullet} x = \{y \mid yFx\}$ and $x \overset{N}{\bullet} = \{y \mid xFy\}$; the superscript N can be omitted if it is clear from the context.

The number of tokens may change during the execution of the net. Transitions are the active components in a Petri net. They change the state of the net according to the following *firing rule*:

1. A transition t is *enabled iff* each input place p of t contains at least one token.
2. An enabled transition may *fire*. If transition t fires, then t *consumes* one token from each input place p of t and *produces* one token for each output place p of t.

Given a Petri net $N = (P, T, F)$ and a state M_1, the following notation is defined:

- $M_1 \xrightarrow{t} M_2$: transition t is enabled in M_1 and firing t in M_1 results in state M_2.
- $M_1 \longrightarrow M_2$: there is a transition t such that $M_1 \xrightarrow{t} M_2$.
- $M_1 \xrightarrow{\sigma} M_n$: the firing sequence $\sigma = t_1 t_2 t_3 ... t_{n-1}$ from state M_1 leads to state M_n via a (possibly empty) set of intermediate states $M_2, ..., M_{n-1}$, i.e. $M_1 \xrightarrow{t_1} M_2 \xrightarrow{t_2} ... \xrightarrow{t_{n-1}} M_n$.

A state M_n is *reachable* from M_1 (notation $M_1 \xrightarrow{*} M_n$) *iff* there is a firing sequence σ so that $M_1 \xrightarrow{\sigma} M_n$. The empty firing sequence is also allowed, i.e. $M_1 \xrightarrow{*} M_1$.

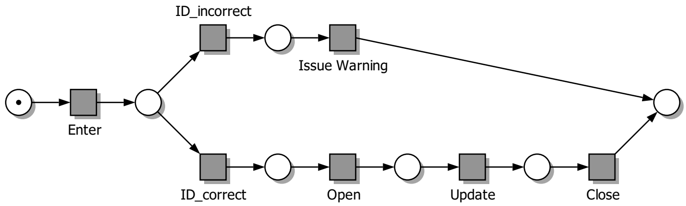

Figure 2: Petri net-model of the workflow.

Transformation to IFnet. Application of the "BPEL2oWFN"-tool to the BPEL code of the process in Figure 1 yields the Petri net depicted in Figure 2. The activities of the workflow are modeled by transitions, which are depicted as green (or gray) boxes. In addition to activities, the "BPEL2oWFN"-tool has introduced extra transitions which stand for the two cases of the exclusive choice. Places – depicted as circles – represent conditions and the state of the workflow is marked by a single token, which is depicted as a black dot which initially resides in the start place. The arcs are depicted as arrows.

3.1.2 Step 2: Petri net to IFnet

The Petri net in Figure 2 models the behavior of a single workflow instance. To check instance isolation, the net is "unfolded" to model two instances of the workflow and their explicit interaction. Interaction between instances of the "Update Patient Record" workflow occurs through access to the patient record, which is a shared, limited resource: multiple instances may attempt to access a specific patient record, but only one instance can hold the record at one point in time.

Modeling Resource Consumption. Resource consumption of a workflow is modeled through a relation $\mathcal{D}$ which denotes the pairs of transitions which obtain and release a resource, respectively. For a Petri net $(N, M) = ((P, T, F), M)$ with initial marking M, $\mathcal{D} \subseteq (T \times T)$ is a binary relation over the transitions of N with the following property:

- For each $(t_1, t_2) \in \mathcal{D}$ there are states M_1, M_2 and firing sequences σ_1, σ_2 such that $M \xrightarrow{\sigma_1 t_1} M_1$ and $M_1 \xrightarrow{\sigma_2 t_2} M_2$. That is, there must be at least one path through the net where t_1 precedes t_2.

Unfolding to IFnet. An IFnet models the interaction of two instances of a Petri net-model. The two instances are denoted "High" (H) and "Low" (L), expressing the difference in their security clearances. For a marked Petri net $(N, M) = ((P, T, F), M)$ and a resource relation $\mathcal{D}$, the corresponding IFnet is a tuple $(P_L \cup P_H \cup P_{\mathcal{D}}, T_L \cup T_H, F_L \cup F_H \cup F_{\mathcal{D}}, M_L + M_H + M_{\mathcal{D}})$ where:

- $((P_L, T_L, F_L), M_L)$ corresponds to the net $((P, T, F), M)$.

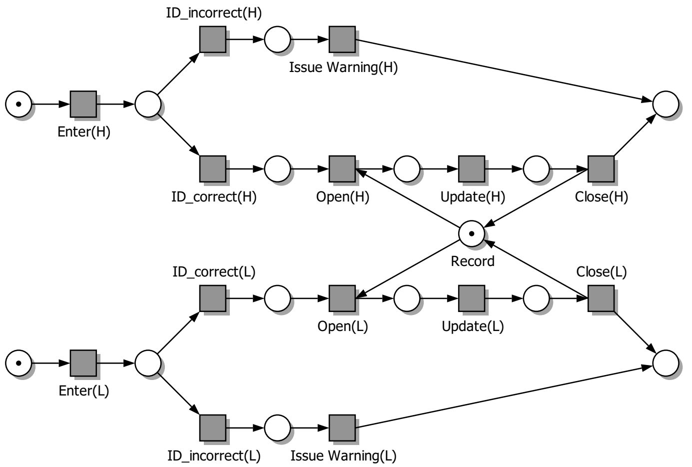

Figure 3: IFnet of the workflow.

- $((P_H, T_H, F_H), M_H)$ is an equivalent net to $((P_L, T_L, F_L), M_L)$ with its elements renamed for distinction. The function $\Upsilon_{T_L \to T_H} : T_L \longrightarrow T_H$ maps the transitions from T_L to their counterparts in T_H.
- $P_\mathcal{D}$ is a set of places which model the blocking of resources. There exists exactly one $p \in P_\mathcal{D}$ for each pair $(t_0, t_1) \in \mathcal{D}$. The function $\Upsilon_{P_\mathcal{D} \to \mathcal{D}} : P_\mathcal{D} \longrightarrow \mathcal{D}$ maps the places from $P_\mathcal{D}$ to the corresponding pair of transitions in T (and therewith in T_L).
- $M_\mathcal{D}$ denotes the initial marking of places $P_\mathcal{D}$. $M_\mathcal{D}$ marks each $p \in P_\mathcal{D}$ with exactly one token.
- $F_\mathcal{D}$ denotes the arcs which connect the places in P to the blocking and releasing transitions in T_L and T_H. For each $p \in P_\mathcal{D}$ with $\Upsilon_{P_\mathcal{D} \to \mathcal{D}}(p) = (t_0, t_1)$ it contains the following arcs:
  - (p, t_0) denotes the blocking of the resource modeled by p through transition t_0.
  - (t_1, p) denotes the release of that resource through transition t_1.
  - $(p, \Upsilon_{T_L \to T_H}(t_0))$ denotes the blocking of resource p through the transition in T_H which corresponds to t_0.
  - $(\Upsilon_{T_L \to T_H}(t_1), p)$ denotes the corresponding release of the resource.

For the Petri net from Figure 2, the resource relation is $\mathcal{D} = \{(Open, Close)\}$, denoting that the transition Open blocks a patient record and transition Close releases it. The corresponding IFnet is depicted in Figure 3. The upper part of the Figure shows the "High"-instance of the workflow and the lower part its "Low"-instance. The patient record is modeled through a token which initially resides in an extra place representing its storage. Whenever one of the Open transitions fires, the token is consumed and the storage place remains empty until the token is returned by the firing of the corresponding Close transition. Inspection of the IFnet model indicates that the interaction of the two instances can lead to a violation of the isolation requirement, a fact that is proven by the following formal verification.

3.2 Static Information Flow Analysis

The possibility of in IF between the "High" and the "Low" instances of the workflow is assessed according to the BNDC property. Originally defined on a process algebra, it is defined for Petri nets in [FGF08]. BNDC rules out any information transmission from the "High" part of a system to its "Low" part. It formalizes information transmission in a notion of non-interference [GM82]: a Petri net fulfills BNDC if, whatever behavior the "High" part of the net exhibits, there must be no observable effect on its "Low" part.

The *Petri Net Security Checker* (PNSC) implements a checking algorithm for BNDC. Specifically, PNSC verifies the so-called PBNI+ property (*Positive Place-Based Non-Interference*) which has been proven to be equivalent to BNDC [BG09]. PBNI+ is checked using a semi-static analysis, which firstly inspects the Petri net for patterns where "High" and "Low" parts might interfere and, subsequently, checks whether these patterns are *active*, i.e. if they can be executed.

The analysis of the IFnet from Figure 3 shows that the storage place (labeled Record in Figure 3) is both an *active conflict place* and an *active causal place*. This means that two types of information flow might exist from the "High" instance to the "Low" instance:

1. Firing of transition Open(H), the patient record is removed from the storage place and transition Open(L) is blocked until the token is returned. Here, the "High" part of the net influences the "Low" part as it prevents the transition from firing. There is an information flow (through a so-called *resource exhaustion channel*) which allows the "Low" part to deduce that "High" is currently holding the patient record.
2. Firing of transition Close(H), the token representing the patient record is returned to its storage place and might be consumed by transition Open(L). Hence, opening the patient record on the "Low" side requires its preceding return on the "High" side: this causality reveals to "Low" the fact that "High" has returned the record.

Although rather simple, this case study illustrates the kind of analyses the framework aims to carry out and the types of information leaks it is able to detect. Current case studies involve more complex workflow models, thereby showing and justifying extensions from the core analysis framework. Particularly interesting for the investigation of data leaks in workflow models is the concept of "swimlane" in BPMN descriptions. Since each swimlane characterizes one type of "actor", e.g. along a sensitive supply-chain, it is relevant and evident to elucidate in a formal manner what these actors can deduce from the others.

4 Related Work

The idea of using information flow control for the verification of workflow models is to the best of our knowledge new. The closest work in this direction is by Hutter and Volkamer. They present an approach for the secure composition of web services in a service-oriented architecture based on language-based information flow techniques [HV06]. The majority of approaches towards workflow security is based on access control models, e.g. [BRV09]. Namiri and Stojanovic propose a pattern-based methodology stipulating the construction of business processes from recurring patterns that are deemed secure [NS07]. While this includes several relevant organizational patterns, such as separation of duties and four-eye rule, it does not focus on information leaks. The REALM approach envisages the automated generation of rules for an access control monitor from a high-level specification language [GLMP05]. Overall, the goal of these approaches is to provide security guarantees concerning subjects' data access. They cannot however detect covert-channels as the one illustrated in the case study.

Considering merely dataflows – an overly simplified form of interference – Knorr presents an approach for the verification of multi-level security policies, such as Bell-LaPadula, in workflow models based on Petri nets [Kno01]. Sun et al. and Trčka et al. propose methodologies for the integration of the dataflow perspective into formal workflow models and the verification for sets of predefined error patterns [SZNS06, TvdAS09]. These approaches do not allow to detect data leaks happening over covert-channels.

5 Summary

This paper presented a framework for the information flow analysis of workflow specifications and demonstrated its applicability in a case study, where pointers to ongoing and related work were given. Overall, the static detection of information flows in workflow models is a novel, promising research direction to ensure formally-founded security guarantees for workflows. However, the enhanced expressive power provided by information flow analysis has a limitation: the interferences detected during the analysis may not necessarily denote an information leak, although they theoretically do so. Hence, obtaining a fine-grained distinction between leaks and necessary flows is necessary. Here, the use of security policies as declassification rules [SS05] might provide a way to distinguish between interferences.

The framework presented in this paper is part of a larger research effort, whose goal is to provide the fundamental building blocks for the forensic analysis of workflow executions. In this setting, a forensic reconstruction algorithm is being developed which allows to extract IFnet models solely from log traces of workflow executions. This allows a posteriori analysis of workflow executions if no explicit model is present. Other covert-channels arising from the dynamics of workflow execution, such as timing and the probability distribution of execution paths, can be detected.

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RFID-based Business Process Improvements – Case Study Results and Recommendations

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Abstract: The success of an enterprise is largely determined by its ability and flexibility to react to changes and its business process stability and safeness. Innovative technologies help to improve the execution and management of business processes and ensure that a competitive position can be achieved or enhanced. Radio frequency identification is such an innovative technology with a high potential of optimisation within business processes for example for reduction of processing time and failure rates. By means of a practical case study this paper gives recommendations and shows how RFID can improve business processes.

1 Introduction

Nowadays companies are facing the challenge of globalization and the resulting increase of competition on a global scale. Results of the globalization are for example the rise in frequency of goods ordered, the need for faster information transfer, and shorter product life cycle times [Ko09]. One way to achieve an efficient organizational performance is to manage and improve the business processes within and across the company. Business process management (BPM) addresses this area and intends to improve processes continuously [MVM09].

Business processes can be classified on three levels: strategic planning, management control, and operational control. On the first level, business processes are processes which govern the objectives of the organization, the changes in these objectives, and the resources used to obtain these objectives. Furthermore, policies that specify the acquisition, use, and disposition of these resources are formulated. Within management control, process managers assure that resources are obtained and used effectively and efficiently for the accomplishment of the organization's objectives. Business processes on operational level assure that specific tasks are carried out effectively and efficiently [Ko09].

The most important aspects of BPM are controlling and measurement of business processes. To improve business processes, they have to be described in a structured way. According to this structured description the potentials for improving the processes can be identified and appropriate modifications can be realized.

One possible enabler to optimize business processes is the adoption of emerging technologies. Automatic identification systems (auto-ID) such as barcode, radio frequency identification (RFID) and sensor technique are such emerging technologies. They are able to automatically identify objects, collect data about these objects and provide this data to computer systems. One of the most significant auto-ID systems is RFID. This technology has the potential to change the way of controlling business processes fundamentally [Gü08]. RFID enables real-time data processing of processes. Hence, information is faster and more precisely available at the point of need e.g. for monitoring processes. RFID technology enables the optimization of multiple business processes and the emergence of new processes called intelligent processes or smart processes which are automatically triggering actions and events [AI08].

The goal of this paper is to show how RFID can improve business processes on a practical case study. The paper is structured as follows: section two describes RFID-based business process improvements in general. A case study which shows business process improvements in a brewery is presented in chapter three. General recommendations for the usage of RFID to improve business processes and a conclusion are given in chapters four and five.

2 RFID-based Business Process Improvements

The technology of radio frequency identification attracts an enormous interest, not only in the research community but also in the industrial field [SG08]. Based on its characteristics, e.g., contactless and automatic capture of data, RFID is an innovative technology for improving business processes, i.e. to increase process efficiency in inbound and outbound flows of goods or in preventing shrinkage and product counterfeiting [Th07].

RFID enables event-driven process management. Transponders, RFID devices and sensors capture states and the location of objects or persons. RFID can be used in many business sectors where a contactless identification of objects or a contactless transfer of data is necessary. However, RFID is not only a technology for identification it also enables real-time data which can be used for improving and controlling business processes [GH07]. This data can be used as decision support for manual and automatic triggering of events. It can lead to a reduction of costs and bring competitive advantages. In association with the automatic reaction of events RFID realizes an important step in the direction of seamless data integrated business processes [Ha08].

In 2008, the authors of this paper carried out an online survey to evaluate experiences and expectations of RFID. Overall, 53 German companies took part in the survey. A result was that most enterprises currently use the RFID technology for tracking and tracing of products (app. 26 percent) and for automating and controlling of processes (app. 28 percent). More than 39 percent of participating enterprises expect a reduction of process costs, the realization of competitive advantages and the reduction of time for the production process.

As mentioned above, the full potential of the RFID technology can only be exploited if the technology is used on all three levels of business process management. Table 1 shows possible advantages using RFID technology (in brief). Each advantage will be identified by an abbreviation in order to relate achieved advantages from the case study which is described in section 3.3.

Operational level:

- OA1: process speedups due to the automation of formerly manual operations
- OA2: comparison of automatically captured real-time data with target data,
- OA3: reduction of time for process life cycle,
- OA4: minimization of failure rate,
- OA5: seamless integration of data (paperless data integration, all data is stored electronically)

Management level:

- MA1: reduction of process costs due to the reduction of the number of process steps,
- MA2: enabling real-time processes [Ha08],
- MA3: more transparency within processes and across process,
- MA4: better possibilities of process control,
- MA5: increase of process flexibility due to real-time data,
- MA6: improvement of inventory management by means of more accurate data and less process time of inventory checking,
- MA7: facilitation of regulatory requirements fulfillment such as documentation of maintenance and tracking of groceries

Strategic level:

- SA1: protection from counterfeiting of merchandise,
- SA2: improvement of process and product quality due to structured, more accurate and seamlessly integrated data on the operational systems [Ha08],
- SA3: Reduction of costs,
- SA4: Improvement of customer satisfaction.

The advantages mentioned above are cross-related. Some of the advantages are characterized below.

RFID enables process speed-ups. Non-conformity costs can be reduced by detecting mistakes made during the distribution process [Go09]. The technology delivers more accurate information and allows information sharing for all relevant processes between all stakeholders along the supply chain [Go09]. Additionally, RFID can utilize the captured data to develop new products and services [TAF09].

If the supply chain is not automated, all operations in the chain need to be carried out step by step manually. The whole process involves a lot of repetitive human tasks, exchange of paper documents, inefficiencies, and errors. Furthermore, processes are difficult to monitor and track. Therefore, it is difficult to gain an overall view of operations and to give information about the state of a process [Al04].

In addition to the importance for tracking and tracing of objects, RFID also supports the management of business processes. The captured data can be used for monitoring and controlling of processes as well as for statistical functions.

3 Case Study

The case study which was developed in the research project "KegMan[1]" examined the feasibility and implementation of a RFID-based tracking and tracing solution for beer kegs (barrel) and its financial implications. For filling the beer aluminum, steel and polyurethane (PU) kegs are used. Annually approximately 30,000 kegs are in circulation. However, an accurate number of which kegs are within the brewery and which kegs are outside the brewery is unknown. Volume types of kegs are 20, 30, and 50 liter. Until now, the brewery uses a manual system for counting and capturing the kegs and a barcode system for tracking pallets. Thus, it is difficult to monitor which customer is currently in possession of which keg and who is responsible for replacing damaged kegs. The goal of the RFID implementation in the use case is to automate the keg management process and to collect information about the location and circulation time of the kegs. The RFID-based tracking solution gives detailed asset states, movement history information and provides accurate turn and loss data about the kegs.

For the identification of kegs during the cleaning and filling process a solution based on low frequency (LF, 125 kHz) is already available. With the system all kegs can be identified on the ampoule filling system. The operating distance for reading is only a few centimeter. As a result of this short reading distance the system cannot be used for automatic tracking of multiple kegs within the whole supply chain.

3.1 Description of Business Processes

The initial state of the whole process for the beer delivery was analyzed and is shown in figure 1. This process consists of the following steps:

(1) When a customer has placed a new order empty kegs are transported by a truck. With this truck the newly filled kegs will be picked up from the brewery (see process step 12).
(2) The empty kegs are counted by an employee and captured on the delivery receipt for the new order.
(3) After the counting process the kegs are transported to an off-site stock ground.

[1] KegMan is a research project to develop an intelligent management system for the consistent tracking of beverage kegs.

(4) Data indicating the arrival is later transferred into the brewery IT-system manually.
(5) For filling the kegs they are transported to the ampoule filling system. The kegs are inspected for visible damages by an employee. If a keg is damaged it will be rejected and repaired later.
(6) At the ampoule filling the residual pressure is controlled and the kegs are cleaned. Afterwards the kegs are filled.
(7) After filling the kegs their weight is controlled.
(8) The keg identifier is captured manually and documented on paper by an employee.
(9) At the end of the day the data on the paper is transferred into the brewery IT-system manually.
(10) The kegs are transported to the warehouse.
(11) The kegs are transported with a fork lift to the picking location and composed on pallets.
(12) After composing kegs a fork lift loads the truck with the ordered kegs.
(13) The loaded kegs are counted manually by the fork lift driver.
(14) Once the truck is loaded, the delivery receipt data is transferred into the brewery IT-system manually.
(15) The truck takes the order to a distributor. Afterwards, the distributor delivers the beer to bars, restaurants or liquor stores and returns to the brewery for servicing and refilling.

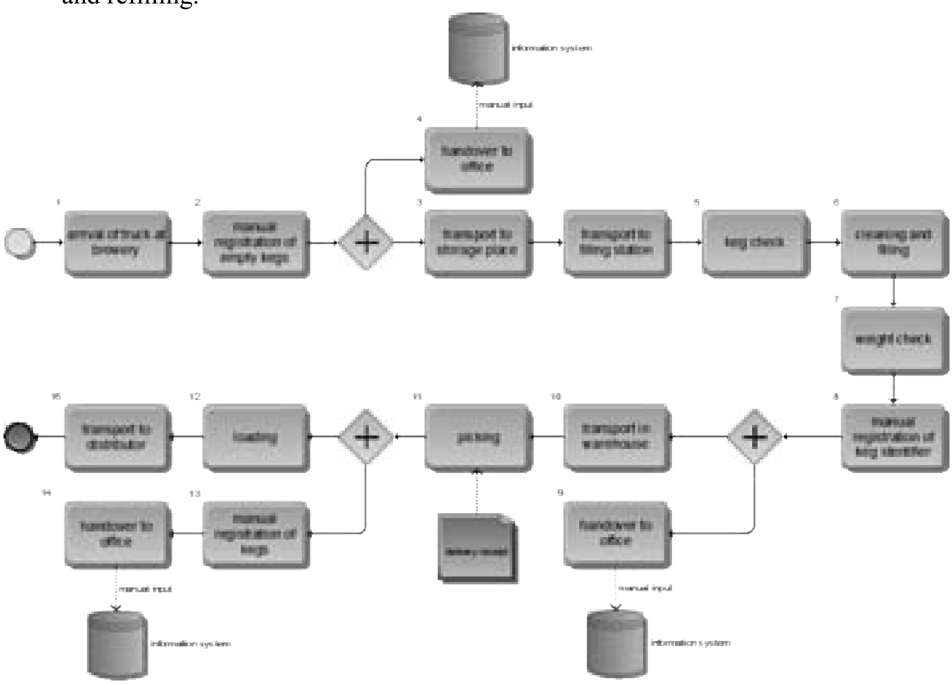

Figure 1: Current business process model for the keg management life cycle

It is important to point out that the manual activities 2, 4, 9, 13 and 14 are highly error-prone. Additionally, the transfer of data from paper to IT-systems is time-intensive and also error-prone. Therefore, a seamless integration of data is required.

As a result of the process evaluation, three sub-processes, which can be supported and improved by RFID, were identified:

1. counting process of returned empty kegs,
2. filling process of the kegs, and
3. loading process of outgoing goods.

Consequentially, the main objective of the case study was to develop an intelligent RFID-based keg tracking system which automatically tracks kegs within the whole supply chain. In addition, data integration needs to be realized without changing the type of media.

To improve the business process the following RFID-based re-engineered process was implemented (see figure 2).

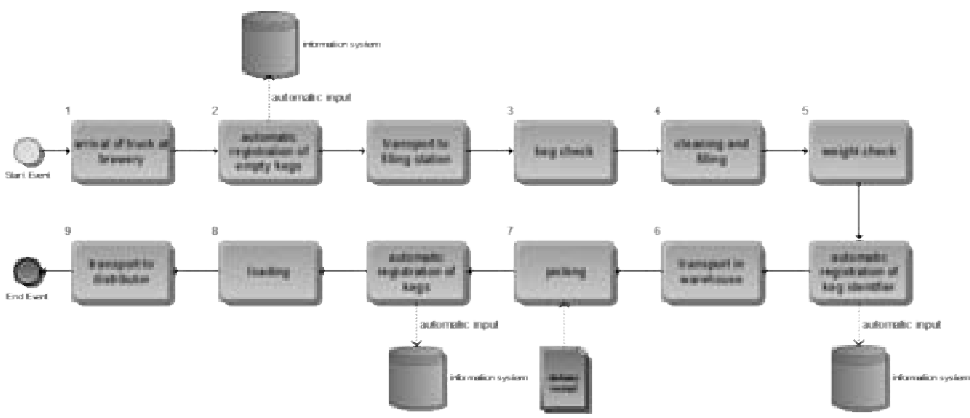

Figure 2: Target state of business process based on RFID

(1) Delivery of empty kegs.
(2) The empty kegs are transported to the off-site stock ground by a fork lift. The fork lift drives through a RFID gate[2] which automatically captures all kegs and sends the number of kegs to the brewery IT-system. Additionally, the number of filling circuits and the date of the last service are checked. If a keg has passed too many filling cycles or if a maintenance service is necessary, the keg is transported to the clearing location.
(3) Before filling the kegs they are inspected for visible damages by an employee.
(4) Cleaning and filling the keg.

[2] A RFID gate consists of at least two RFID antennas which communicate with a RFID reader.

(5) Measuring the right weight of the filled kegs. Additionally, an installed RFID reader captures the transponder identification number (ID) of each keg. This number is automatically combined with the keg number, the beer charge, and the date of filling. All data is sent to the IT-system of the brewery.
(6) The kegs are transported to the warehouse.
(7) Composing the kegs on pallets according to the delivery receipt.
(8) When a fork lift loads the truck with the ordered kegs it passes another RFID gate. The transponder ID is captured and stored automatically within the brewery IT-system.
(9) Shipment to the distributor.

The results of the changed processes are:

- Reduction of the number of activities,
- Transformation of manual to automatic activities,
- Decrease of error-prone activities,
- Increase of process transparency, and
- Decrease of process execution times.

After the process re-engineering the selection of appropriate RFID readers, antennas and transponders as well as the development of the software for the RFID system were made. The biggest obstacle however was the material of kegs. In general metal dramatically reduces the operating range of reading. Due to the width of the gate for outgoing goods a reading range of approximately four meters is required. With conventional RFID-Tags this distance cannot be realized. According to the reading range, the position of the transponder on the kegs is another important aspect. Hence, it is important, that the selected position prevents transponders from damages.

As a result of the analysis two different transponders were identified; one for the metal kegs another for the PU kegs. In order to realize operational reliability of the RFID system a lot of tests were necessary. Tests in the brewery have shown that it is possible to realize a 100 percent reading accuracy for the bulk identification of the required 24 kegs (six kegs on a pallet, four pallets on a fork lift).

3.2 Profitability Analysis

After the tests have been completed successfully a profitability analysis was executed. The improvement of business processes with the launch of the radio frequency technology in breweries is particularly evident in a profitability analysis. As part of the FIM[3] research project "Cost-benefit analysis for an RFID-based identification system for kegs in breweries", a computational tool for calculation of KPI (Key Performance Indicator) has been developed and is used for decision support for launching an RFID project. The tool reflects especially the reduction of keg circulation time that results from changing business processes. According to this tool an analysis to determine the benefits has been carried out in the KegMan research project.

For this, the costs of the RFID system have been captured first. They include both hardware and software for the launching of the system in the brewery. Furthermore, the estimated cost of the project management and the operating cost per year were considered. The cost rates are based on inquiries for RFID hardware and software from different vendors in 2009 and consider the brewery's specific requirements. The costs of the transponder depend on the one hand on the quantity required for the brewery. On the other hand the mounting of the transponder swayed the cost for the transponder. Some information was not available and could therefore only be estimated.

In addition to the costs for launching the radio frequency technology in the brewery, a number of brewery-specific basic data for a profitability analysis are needed. These include annual production of draft beer, information about the kegs used (size, type, quantity and average purchase price), number of required RFID readers, annual loss rate of kegs, repairs and maintenances per year, average repair and maintenance cost per keg complaints per year and number of loading lanes. All those information varies depending on the brewery.

With the collected cost rates various potential savings could be considered. The major potential is derived by reducing time of circulation. By reducing cycle times especially the stock of kegs can be minimized. Thus, the liquidity of the company may be increased.

Furthermore, by launching the RFID technology, the maintenance process could be improved. In contrast to the initial process the kegs can be maintained regularly based on the number of filling circuits. This reduces the chance of faulty kegs delivered to the customers and decreases the number and cost of customer complaints. Although the regular maintenance causes higher cost the customer satisfaction could be increased. Furthermore, the customer loyalty was strengthened.

[3] Research Institute for Management and Beverage Logistics (FIM), website: https://www.vlb-berlin.org/cms/front_content.php?lang=1&client=1&idcat=12&idart=11&changelang=2

Initially, the brewery did not always know where their kegs are located and who is currently in possession of them. This caused massive costs for the brewery. With the RFID-based tracking of kegs and the resulting increase of process transparency, the loss of kegs could be reduced. The brewery knows the location of their kegs and who is in possession of them any time.

With that information, the amortization could be calculated, as shown in table 1.

Table 1: Results of Profitability Analysis

investments for RFID system	amount to be invested		€	**176,125.41**
annual savings by RFID system	reduction stock of kegs		€	47,303.53
	reduction loss of kegs		€	46,912.50
	reduction of complaints		€	3,000.00
		sum:	**€**	**97,216.03**
annual cost of RFID system	operating cost p.a.		€	7,500.00
	maintenance of the kegs (additional annual cost by regular maintenance)		€	17,242.11
		sum:	**€**	**24,742.11**
Amortization		**years**		**2.43**

As a result of the profitability analysis the RFID system can be amortized after roughly 2.5 years.

3.3 Benefits for the Brewery

In summary, the following benefits categorized into three levels could be realized.

Operational level:

a. Increased process speed (OA1):
Due to the automation of formerly manual operations the process speedup was increased. Until now incoming empty kegs have to be counted by an employee manually. This process will take less time by using RFID.
b. Reduction of circulation time (OA3):
Due to the tracking of kegs based on RFID the circulation time can be monitored and analyzed. Based on these analyzed data process bottlenecks can be identified.
c. Reduction of asset loss (OA2):
Due to the real-time information about the location of kegs a reduction of asset loss can be achieved. Thus, a significant added value - a new keg costs 130 EUR but the keg deposit is only 30 EUR - can be generated.
d. Elimination of inventory inaccuracies (OA4):
The manual counting process causes inventory inaccuracies. With automatic counting of kegs the error rate can be decreased.

e. Reduction of complaints (OA4 and SA4):
   The regular maintenance of kegs enables the reduction of faulty kegs delivered to the customer. As a result the number of complaints can be decreased. In addition the customer loyalty is strengthened.
f. Seamless data integration (OA5):
   Due to the automatic capturing of kegs seamless data integration can be realized and less errors occur. Manually hand-filled forms are replaced by electronic and paperless data capturing. The employees do not have to gather the data on a paper sheet and transfer the data in the information system.

Management level:

g. Identification of returned empties (MA6):
   The bulk identification of the incoming empty kegs provides accurate data of the number of available kegs.
h. Improvement of the maintenance process (MA1 and MA2):
   In contrast to the initial process the kegs can be maintained regularly by the number of filling circuits. The necessity of the next service can be determined in order to discharge the keg and to arrange maintenance of the keg.
i. Better visibility of keg stock (MA3):
   Resulting from real-time data of the available kegs a better visibility of the keg stock can be realized. Thus, the capability to react flexibly to an extraordinary order can be improved.
j. Support for business process management (MA4):
   The use of RFID technology enables the automatic monitoring of stock levels and product movements. RFID produces a positive impact on supply chain performance since the way of information between brewery, distributor, and gastronomy can be optimized. Furthermore, the reliability of delivery on time and the quality can be increased.

Strategic level:

k. Statistical information (SA2):
   The RFID readers in the brewery capture up-to-date keg information. This information can be analyzed for statistical purposes and provides a basis for the decision making process.
l. Increased customer satisfaction (SA4):
   Due to the faster reaction of complaints and the lower number of faulty kegs the customer satisfaction may be increased, resulting in higher customer loyalty.
m. Reduction of costs (SA3):
   Firstly, the acquisition of new kegs can be reduced; secondly, the costs of complaints can be decreased; thirdly, less capital is tied up and the liquidity of the enterprise may be increased; fourthly, the sales volume can be augmented.

4 Recommendations

Based on the experiences from this case study and several further research projects with RFID technology realized by the authors some recommendations can be given.

A precondition for a successful use of the RFID technology is a clearly defined business case. For this business case the processes have to be analyzed extensively. The analysis may help detect inefficiencies, error-proneness and reasons for quality problems in the processes [Gü08].

In order to achieve the full potential of the RFID technology the captured RFID data has to be made available to all relevant business processes.

The tight integration of the technology into existing IT infrastructure (e. g. ERP and WMS) is crucial to achieve the positive impacts of RFID. For large-scaled RFID applications existing middleware solutions for filtering and processing RFID data is recommended. In addition, the use of a middleware simplifies the integration of the RFID system.

The implementation of a tracking and tracing system within the whole supply chain requires that all partners combine the flow of goods with the corresponding flow of information [GS09]. On the one hand this involves the exchange of captured RFID data with business partners. On the other hand this requires management rules and rights for all partners.

In order to achieve a stable running RFID system the technical properties of transponder and RFID devices must be substantially tested. An optimal configured RFID system depends on different aspects, e. g. environment, material of tagged objects, and transponder position on the object.

The RFID transponder and readers require a high investment. Consequently, the feasibility of an RFID adoption has to be taken into account.

5 Conclusion

This paper presented an overview how RFID can help to improve the controlling and measurement of business processes. Based on a case study the positive impact of RFID within the beverage industry was depicted. A comparison of the initial processes with RFID-based re-engineered processes was shown. Subsequently, the benefits for the brewery were listed. Finally, recommendations for a successful use of RFID for the improvement of business processes and their management were given.

The consequent application of the RFID technology leads to detailed and accurate data of the objects and processes being surveyed. This data can be used by decision makers at different levels of the organizational hierarchy and lead to considerable operational and strategic benefits [Gü08].

In the first phase of the case study a local solution within the brewery was developed. For the next step a strategic roll-out in an inter-enterprise application setup is planned. The involvement of supply chain partners (e. g. distributors) can maximize the positive impact of the RFID technology. In the same way the costs for transponders and RFID hardware can be shared by partners. Thus the ROI can be achieved in a shorter time. In addition, all partners may gain significant and tangible competitive advantages.

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Measuring the Progress of Reference Model-Based Business Process Modeling

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Abstract: Business process modeling plays a major role in industry and academia. As a result, current research focuses on its assistance. Business process modeling is a time-consuming task and its effort is hard to predict, and a plethora of concepts exists for facilitating and improving it. A concept that has not been studied yet is prediction of the remaining effort of business process modeling. In this paper we tackle this issue and suggest a solution for measuring the progress of business process modeling. Our solution is based on the assumption that a reference model is given representing a best practice of a business process. In addition, a set of process variants exists for that reference model. Under these conditions, we propose two measurement approaches that base on the longest common subsequence algorithm and determine the effort required to complete business process modeling. The main benefit of the approaches is the possibility of effectively structuring and monitoring the development of business process modeling projects.

1 Introduction

The importance of business process modeling (regarded as the process of creating business process models) nowadays is undeniable. It plays a major role in many fields both in industry and academia [In09], such as business process management and information system development. Business process models are used in organizations for documentation issues, for decision support about process development and design, for monitoring of process executions, and for analysis of technology support [Ag04].

Quality and ease of modeling are two of the needs that have been acknowledged for business process modeling [In09]. As a result, much research and many initiatives focus on assistance during its development. For example, existing works try to facilitate and improve business process modeling by applying process mining [Aa07], by defining metrics for business process models [Me08] and by providing tools that facilitate modeling and guarantee correctness [HKL08, MM09]. Consequently, new ideas can be studied for improving and facilitating business process modeling, and the impact and benefits of their application must be analyzed.

An idea that has not been studied for business process modeling is the application of progress measurement. Progress measurement of processes is a common activity in many fields, but it has not been taken into account for business process modeling yet. Progress measurement is usually related to project management, and allows people to precisely inform about process status and the amount of work that has been carried out at a given moment. Therefore, prediction of work completion is facilitated.

The aim of this paper is to adopt the idea of progress measurement in order to facilitate business process modeling. The solution that is presented assumes two conditions. Firstly, it assumes the existence of a reference model representing a best practice of a business process (e.g. an ITIL model). This assumption can always be met thanks to existing techniques for inferring reference models [LRW08]. Secondly, the solution assumes the existence of a set of process variants for the reference model.

Under these assumptions, two measurement approaches are presented. The *strict measurement approach* assumes that the process designer requests a full compliance of a business process model under construction with a reference model and its process variants. In this case, the approach estimates the modeling progress based on the number of operations that are necessary in the business process model under construction to comply with the reference model. The *relaxed measurement approach* assumes that the process designer is looking for a close (non-full) compliance with the reference model. It is a relaxed version of the prior approach.

Both approaches base on the longest common subsequence (lcs) algorithm, for which efficient versions exist even for more than two input sequences [Ba07]. By applying the lcs algorithm for our purpose, we can detect the longest, not necessarily contiguous, sequence of activities that two business process models have in common. Inputs for the algorithm are activity labels of business process models.

Application of progress measurement will be shown for a modeling support tool. The recommendation-based editor [HKL08] suggests users appropriate business process models or fragments that are similar to the ones that they intend to create. The application of the measurement approaches in this context might help users to choose business process models that will allow them to finish modeling faster. Another advantage is that users can request the compliance with a reference model, and compliance can be regarded as related to the quality characteristic of completeness of a business process model (provision of complete information) [BGR06].

The paper is organized as follows. Section 2 describes the measurement approaches. Section 3 shows application of progress measurement in the recommendation-based editor. Section 4 discusses about the solution that is presented. Section 5 presents related work. Finally, Section 6 summarizes our conclusions and future work.

2 Measurement Approaches

The measurement approaches base on two assumptions in order to predict the effort that is required to complete business process modeling.

Assumption 1. A reference model is given that describes a best practice.

Assumption 2. A set of process variants exists for this reference model and are stored in a repository.

The reference model may be, for example, a SCOR, ITIL or CobiT model. In case that no reference model is given, [LRW08] have suggested a heuristic method to determine a reference model from existing business process models. Consequently, assumption 1 can be derived, while 2 must be given.

The measurement approaches do not consider the behavior of activities business process models (branching, merging, fork, join, etc.). Instead they take activity labels (names) as input. In the rest of Section 2 we treat activity labels as letters. For example, "fill customer information" or "choose extras" are represented as "A" or "B" for the sake of understandability and simplicity.

[KSR10] found out that the semantics of process element names is more important for users than syntax in tools that assist users in their modeling task. The reason for that finding is that structuring of process elements is easier than creation of business process models (a model recommendation can be regarded as an inspiration that can individually be adapted and structured).

Certainly, process elements can be labeled with different styles (e.g. verb-object or action-noun) or using different vocabulary (thus synonyms, homonyms or hypernyms can arise), which hampers the reduction to letters. An initial (semi-) automatic approach has been proposed to detect the labeling style and to uniform labels to a preferred style [LSM09]. Unambiguities in process element labels can also be detected using the approaches presented in [EKO07, HKL08]. Therefore, the substitution of process labels with letters is justified, assuming that techniques to detect unambiguity are applied and inhomogeneous labeling styles are unified prior to the usage of the measurement approaches.

Figure 1 shows the scenario for application of our measurement approaches. A process designer is creating a business process model that should comply with a reference model. She is also using a repository of business process models from which she obtains recommendations for creating her model. The modeling progress is calculated on the basis of the compliance of the process being designed (i.e. the business process model under construction) with its reference model and a set of process variants. The process variants, which are stored in the repository, are variants of the reference model. The process designer can decide between the strict and the relaxed measurement approaches to calculate the modeling progress.

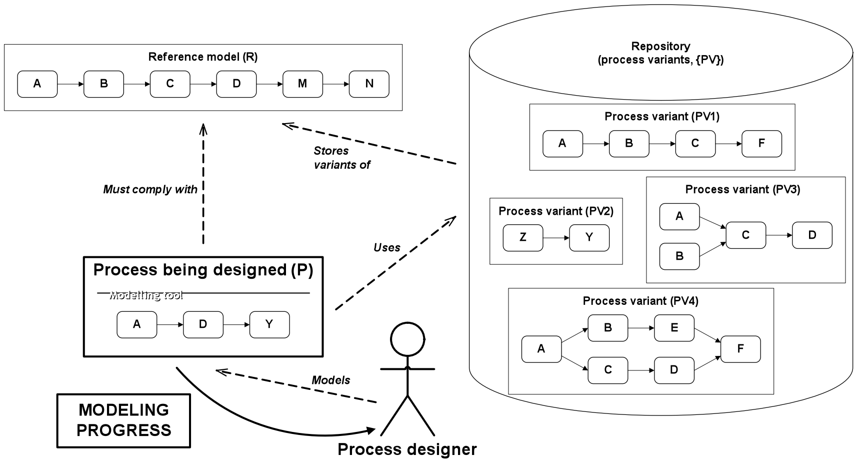

Figure 1: Scenario for application of the measurement approaches

The intention of both approaches is to find the smallest set of operations (insertions and/or deletions) that is required to complete reference model-based business process modeling on the basis of lcs. For example, let "ABCDMN" be a reference model (abstractly) and let "ADY" be a process being designed, then the result of lcs for them is "AD". If lcs is not empty, then subsequently the diff method determines the number of change operations that are necessary to transform the process being designed into a business process model that is compliant with the reference model. Based on the change effort, the remaining work that is required to obtain a compliant business process model can be calculated.

The following abbreviations are used in the rest of Section 2. 'R' refers to the reference model with which a business process should comply. The process being designed is referred to as 'P'. The set of process variants that are stored in a repository are referred to as '{PV}'. Each process variant is referred to as 'PVX', where 'X' is a number that identifies it. These abbreviations have been included in Figure 1, which is also used as an example to show the measurement approaches.

The next subsections present the strict and the relaxed measurement approaches in detail. The strict measurement approach assumes a full compliance with the reference model and its process variants, whereas the relaxed one relieves this requirement. The process designer can decide what kind of compliance she desires.

2.1 Strict Measurement Approach

Development of the strict measurement approach consists of eight steps.

1) Find dependency between P and R and between P and {PV}

The intention of the first step is to ensure that the activities of P are related to R or to any process variant of {PV}.

Input: P, R, {PV}

Based on this input, lcs between R and P (lcs_1) is determined. Subsequently, lcs between P and {PV} (lcs_2) is computed. The calculation order of lcs_1 and lcs_2 does not matter. lcs_2 could be determined first and then lcs_1. In case that neither lcs_1 nor lcs_2 have a solution (i.e. lcs_1 is " " and lcs_2 is " "), then modeling progress cannot be calculated. No solution implies no dependency between the business process models exist. Progress measurement continues if at least a solution is found. In addition, the results of lcs_1 and lcs_2 do not need to be identical. Shorter results mean that more change operations are required to transform a business process model into another and to finally provide full compliance. The number of change operations affects modeling progress.

Output: lcs_1(P,R), lcs_2(P,{PV}) (i.e. lcs of P and each process variant of {PV})

Result for Figure 1: lcs_1(P,R) is "AD", lcs_2(P,PV1) is "A", lcs_2(P,PV2) is "Y", lcs_2(P,PV3) is "AD", and lcs_2(P,PV4) is "AD".

2) Find dependency between R and {PV}

The intention of the second step is to find a dependency between R and {PV}. This step is also a preparation operation for step 3.

Input: R, {PV}

Based on this input, lcs between R and {PV} (lcs_3) is determined. The following steps of the strict measurement approach are only applicable for process variants where lcs_3 has a solution. The repository can include process variants that have activities in common with P but not with R (e.g., PV2 in Figure 1, which includes "Y"). Such process variants are not further considered because they do not comply with R.

Output: lcs_3(R,{PV})

Result for Figure 1: lcs_3(R,PV1) is "ABC", lcs_3(R,PV2) is " " (empty), lcs_3(R,PV3) is "ABCD", and lcs_3 (R,PV4) is "ABCD". Consequently, PV2 is not further considered.

3) Find the "highest" compliance of {PV} with R

The process variants have a different compliance degree with the reference model. A full compliant process variant includes all activities of the reference model. The intention of this step is to find the process variant(s) that incorporates the highest compliance with a reference model. Parsing of the business process model or process variants is performed on the basis of the Refined Process Structure Tree [VVK09].

Input: lcs_3(R,{PV}) where lcs_3 is not " "

Based on this input, the absolute lcs (lcs*, longest lcs_3) is calculated.

Output: lcs*(R,{PV})

Result for Figure 1: lcs* is "ABCD".

4) Determine the distance between P and the "highest" compliance of {PV} with R

For the strict measurement approach, we assume that the process designer desires full compliance of P with R and {PV}. The intention of this step is to determine the operations (specified as '[insertion or deletion, position, activity label]', where insertions are represented with the symbol "+" and deletions with the symbol "-") that are necessary to extend P with lcs*. Then P incorporates the highest compliance degree of {PV} with R.

Input: P, lcs*

> Based on this input, P is extended with the activities that are part of lcs* but not of P. It is then denoted as P'. In case that no operations were necessary, then P and P' would be identical.

Output: P'

Result for Figure 1: insertions of "B" at the second position of P ([+,1,"B"]) and of C at the third position ([+,2,"C"]) are necessary. P' is "ABCDY".

5) Apply lcs* for {PV}

The intention of this step is to determine the activities that are part of {PV} but not of lcs* or P'. As P' incorporates lcs*, each process variant of {PV} is extended so that lcs* holds for all of them. This step is a preparation operation for the step 6.

Input: P', lcs*, {PV}

> Based on this input, each process variant is extended so that lcs* holds. The result is denoted as {PV'}.

Output: {PV'}

Result for Figure 1: PV1' is "ABCDF", PV3' is "ABCD" and PV4' is "ABCDEF"

6) Determine the difference (diff) between P' and {PV'}

The intention of this step is to determine the smallest set of operations for turning P' into {PV'}, and consequently to determine all the activities that are part of in {PV'} but are not yet of P'. This step guarantees full compliance of P' with {PV'}.

Input: P', {PV'}

> Based on this input, P' is extended on the basis of {PV'}. The result is denoted as P''. This operation excludes activities that are unique in P' (in the example, "Y"). We assume that the process designer is not modeling an identical process variant thus she is free to insert as much unique activities as she likes in the process being designed.

Output: P''

Result for Figure 1: two insertions (diff(P',PV1') is 1, [+,5,"F"]; diff(P,PV3') is 0; diff(P,PV4') is 1, ['+',5,"E"]) are required to make P' fully compliant with {PV'}. P'' is "ABCDYEF".

7) Determine the difference (diff) between P'' and R

This step determines the operations that are necessary in P'' to fully comply with R.

Input: P'', R

> Based on this input, P'' is extended with the activities that are part of R but not yet of it. The result is denoted as P'''.

Output: P'''

Result for Figure 1: P''' is "ABCDYEFMN", which results from two insertions in P'' ([+, 7, "M"], [+, 8, "N"])

8) Calculate the progress

The result of this step is an estimation of the percentage of effort that has already been carried out in P. It is calculated on the basis of the following formula:

$$\text{Modeling\_Progress} = \frac{length\ (lcs_1(P,R))}{length\ (lcs_1(P,R)) + number\_of\_operations}$$

For the example, $\text{Modeling\_Progress} = \frac{2}{2+6} = \frac{2}{8} = 0.25$, where length($lcs_1$ (P,R)) is the number of activity labels of lcs_1 ("AD") and the number of operations corresponds to the operations determined in steps 4, 6 and 7 (2 operations in each step). This modeling progress result means that the process designer has modeled 25% of her business process model (with respect to full compliance with R) in P, assuming that she will use {PV}. In the next subsection we discuss the relaxed measurement approach, which eases the compliance degree.

2.2 Relaxed Measurement Approach

The relaxed measurement approach assumes that a process designer does not aim to obtain full compliance of P with R and {PV}, but she is satisfied with a close (non-full) compliance. The relaxed version results from the following modifications:

- The process designer can consider process variants that are not compliant with R but have common activities with P. This eliminates step 2 of the strict measurement approach. Referring to Figure 1, PV2 would be further considered.
- The process designer can specify her compliance preference to {PV}, for example, based upon the frequency of activities in {PV}. The frequency is shown to the process designer in descending order where the most frequent activities (e.g., F occurs twice, E and Z once) are shown on the top. For instance, in Figure 1 the process designer may desire activity E in her business process model instead of F even if F occurs more times.
- No full transformation of P'' into R is required. The process designer decides what activities of R she desires to include in her business process model.

The advantage of this approach is that process designers can browse the set of remaining activities and opt for specific ones. For example, on the basis of Figure 1 and referring to the steps of the strict measurement approach, if a process designer (1) desired no compliance with {PV} (P' and P'' would be identical; no operations would be determined in step 6), and (2) decided not to include "M" in her business process model (no full compliance with R is required; just an operation would be determined in step 7), then $\text{Modeling\_Progress} = \frac{2}{2+3} = \frac{2}{5} = 0.4$, where three operations of the strict measurement approach would not be necessary. Therefore, the process designer would have modeled 40% of her business process model (for non-full compliance with the R) in P.

In summary, the relaxed measurement approach can be regarded as the upper bound of modeling progress and the strict one as the lower bound. In this sense, if a process designer decided not to comply with {PV} and not to include more activities of R (in step 7), then the modeling progress would be 100% (maximum upper bound).

3 Progress Measurement in a Recommendation-Based Editor

A recommendation-based editor for business process modeling [HKL08, KHO10] is used as an example of application of the measurement approaches. The editor is characterized by the use of a recommendation engine that suggests business process models or model fragments from a process repository in order to help process designers complete a business process model under construction.

The process repository is populated with business process models that are stored in the repository after their completion. These business process models are then accessible and thus can be re-used. To retrieve the models, the recommendation-based editor provides: 1) a query interface that allows users to request business process models or fragments that are of interest to them (e.g. by providing the name of a model and its first and last elements), and; 2) a recommender component that automatically suggests appropriate process model fragments for model completion. The decision for a recommendation mainly depends on the score value (Figure 2).

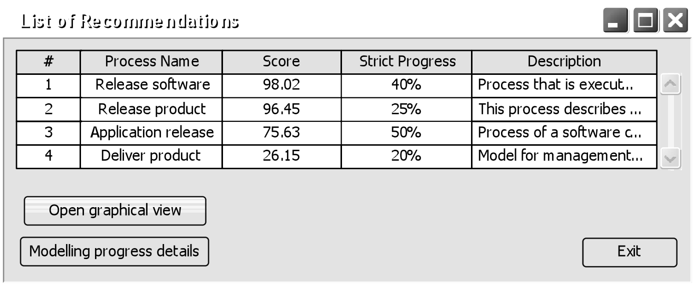

Figure 2: Progress measurement included in a modeling support tool

The score value specifies the linguistic similarity between business process models and the query input. If a user is interested in a recommendation, then the graphical view of the business process model can be opened (button "Open graphical view").

If progress measurement is not taken into account, users have to decide by themselves which recommendation would result in the fastest completion of a business process model. In Figure 2 the first two recommendations have a similar score value. The progress value is an additional decision support in favor of a recommendation.

Another advantage of the integration of progress measurement into this modeling tool is to inform users about the compliance of the recommendations with a reference model. The score value does not consider the order of activities in contrast to the measurement approaches. A high score may result from processes having a low compliance degree. When clicking on the button "Modeling progress details", all the operations that are necessary to complete a business process model are listed.

More concrete details about how modeling progress is measured in the recommendation-based editor are out of the scope of this paper.

4 Discussion

Discussion about the measurement approaches focuses on their effectiveness and on further application areas of progress measurement of business process modeling.

4.1 Effectiveness of the Measurement Approaches

As explained in Section 2, our measurement approaches assume two conditions, where the second one must be fulfilled: a set of process variants of a reference model (with which a process designer wants a business process model to comply) are given. Companies that use the ITIL standard usually customize its models and create process variants. Thus, our assumptions are realistic.

The measurement approaches provide an estimation of the required effort to complete business process modeling. If a process designer had a completely different business process in mind (that only closely resembled the reference model and its process variants), then the progress value could only be regarded as an approximation.

One can criticize the effectiveness of our measurement approaches due to the limited focus on activity labels. Even if the approaches do not consider the behavior of business process models, they consider the order of activities. For this, the diff method reorders the remaining (missing) activities needed so that a business process model under construction is analog to the reference model.

4.2 Further Application Areas of Progress Measurement

Progress measurement could be applied in other business process modeling contexts. For instance, in collaborative, on-line business process modeling the measurement approaches might be used to monitor the development of business process modeling projects. In such collaborative settings, process designers store their models in open repositories and make them available to others. Given the large amount of business processes, it should be easy to determine a reference model (using the technique of [LRW08]) to measure the modeling progress and monitor collaborative activities.

The measurement approaches might also be incorporated in approaches that calculate the similarity or compliance between business process models based on their behavior (some examples are shown in Section 5). Existing works that identify the compliance degree disregard the linguistics of activities and just focus on structure and behavior of business processes. Our measurement approaches are complementary to behavior-based compliance measurement.

Finally, progress measurement could be applied in organizational modeling approaches that model business processes from existing information and/or other models (e.g. [Sc00, VSP08]). On the basis of the proportion of elements that are present in a business process model, modeling progress might be estimated.

5 Related Work

We are not aware of any work that has addressed progress measurement of business process modeling. Nonetheless, five streams of work are related to this paper: (1) progress measurement of processes, (2) application of lcs, (3) measurement of characteristics of business process models, (4) compliance of business processes, and (5) similarity between business process models.

Progress measurement of processes is a common practice in many fields such as project management [CI06], software engineering [LB06], industrial engineering [BW04] and construction [Zh09]. It is used to improve knowledge about process development and status. These works confirm that progress measurement is an important and common activity. However, the nature of the processes of these fields is different from business process modeling (e.g. in its description). Therefore, their measurement approaches cannot be directly applied to business process modeling.

Use, application and adaptation of lcs is common in many research fields such as image pattern recognition [LSY89] and bioinformatics [JP04]. Although lcs has been used in business process management [GCC09], no work has applied it to measure the progress of business process modeling.

Within business process management, several works deal with measurement of different characteristics of business process models in order to evaluate their useful-ness (e.g. [Me08]). These characteristics are complexity, understandability, quality, entropy, density, cohesion and coupling [Go10]. The main difference of our measurement approaches is that they do not only aim to improve knowledge about and quality of business process models, but also to accelerate process designers' work.

Some works address compliance of business process models with requirements such as regulations [Kh08], data objects lifecycles [KRG07] and goals [KK97]. Compliance can be measured based upon business process management platforms [LSG08] or behavioral profiles [We10]. The reference models that are used in our measurement approaches can be regarded as another type of requirements. Our measurement approaches determine compliance on the basis of activity labels, but they can easily be applied to behavioral-based approaches.

Research on similarity between business process models (e.g. [MAW08, DDG09]) is also related to this paper. In [GCC09], similarity to reference models is addressed. Most of the works focus on measuring similarity between business process structures, and none address measurement of modeling progress. Nonetheless, their methods for similarity measurement could be adapted for the latter purpose.

Last but not least, prediction of completion of business process execution [Aa09] is a visionary proposal that is based on features of navigation systems. Since completion of a journey can be predicted, completion of business process execution could also be done. However, the way to carry out the prediction has not been determined yet.

6 Conclusions and Future Work

Business process modeling is essential in many fields nowadays, and much research and many initiatives have been proposed in order to facilitate and improve its development. Nonetheless, new ideas can be analyzed and their benefits must be studied.

This paper has proposed progress measurement as a new practice for supporting business process modeling, whose application has not been previously analyzed. As a result, two measurement approaches have been presented for reference model-based business process modeling. Both approaches calculate the modeling progress based on the compliance of activity labels and use the lcs algorithm for this purpose.

Progress measurement can improve business process modeling from two perspectives. From a perspective of ease of modeling, business process modeling is improved by providing information about the amount of work that has been carried out and/or that is still needed. Process designers' work might also be accelerated. From a perspective of quality, business process modeling is improved by providing information about the completeness of a business process model. Application of progress measurement in a modeling tool and discussion about the paper have also been presented.

As future work, we plan to apply progress measurement in actual settings and projects, to analyze the efficiency of the recommendation-based editor when calculating modeling progress, and to further study application of progress measurement in other methods for and applications areas of business process modeling.

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A Tool for Evaluating the Quality of Business Process Models

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Abstract: Modeling business processes is an essential task when aligning, improving or automating existing business processes. To be efficient in such tasks, a business process model must be understandable, reusable and easily maintainable. For assessing the quality of a business process model, a set of quality metrics have been proposed either by adapting some mature software quality metrics, or by defining new metrics specific for business processes. The aim of this paper is to classify the quality metrics proposed so far within a framework defined in terms of design perspectives, and to implement this framework in a tool assisting in the evaluation of the quality of business process models. This tool helps the designers to select a subset of quality metrics corresponding to each design perspective and to calculate and interpret their values in order to improve the quality of their model.

1 Introduction

Quality is one of the major topics in the process modeling domain as much as it is in software modeling. Evidently, obtaining a high quality business process model (BPM) minimizes design flaws, avoids dysfunctions of the process once deployed, and helps the designer to produce a BPM that is easier to understand and maintain. The importance of BPM quality motivated several researchers to propose solutions to improve business process models. In fact, a variety of standards (cf., [SS99] [Gr03]) and frameworks (cf., [NR00] [KSW02]) has been proposed to define, manage, ensure and/or improve the quality of business process models. These standards and frameworks require/use a set of *quality metrics* was proposed to evaluate the quality of a BPM.

According to [ISO98], a quality metric is a quantitative scale and a method that can be used to determine the value taken by a characteristic of a software product. Exploiting the maturity of software quality metrics, several researchers adapted metrics from the field of software engineering for business process models (*cf.,* [CMN+06] [GL06]). The adaptation is justified by the fact that a business process model described by EPC (Event-Driven Process Chain), Petri nets, activity diagrams, BPMN (Business Process Management Notation) [OMG04], or any other modeling language manifests a great number of similarities with software models [VCM+07].

Our contribution in this paper is to propose a classification framework and a tool, baptized *BPMN Quality*, for evaluating the usability of process models. The originality and advantages of our proposition can be summarized in the following five points:

(1) The framework for classifying quality metrics accounts for BPM perspectives (*e.g.,* informational, functional, organizational and behavioral). This provides the designer with a better usage of quality metrics. Indeed, depending on his/her perspective, a designer would be examining only a subset of metrics pertinent to his/her point of view: the selected metrics are defined in terms of business process elements that he/she is interested in. In addition, once a decision is made, for instance, to restructure a BPM to improve a given metric, the designer knows the impact of his/her decision on other metrics dealing with other perspectives; that is, the BPM elements involved in the examined metric provides for traceability among the various perspectives.

(2) The *BPMN quality* tool implements all metrics proposed in the literature. Hence this tool proves for experimental evaluations of these metrics with different process model categories (administrative, workflow, etc.).

(3) *BPMN quality* takes as input a business process represented in XMI [OMG09], the OMG (Object Management Group) standard for model exchange. So, it can be integrated in any modeling tool which supports XMI interchange format.

(4) *BPMN quality* interprets results against various quality dimensions, which assists a designer in making judicious decisions.

The remainder of this article is organized as follows: In section 2, we overview quality metrics defined in the business process domain. In section 3, we first present a packaging of the BPMN meta-model [OMG04] which highlights the concepts pertinent to each perspective and the inter-dependencies among the perspectives. Secondly, we use this packaging to present our classification framework. In section 4, we present our tool *BPMN Quality* which implements the classification framework proposed in section 3 and the metrics algorithms defined in the literature. Finally, we conclude this paper with a summary of the presented work and an outline of its extensions.

2 Overview on current metrics for BPM

Several researchers have already identified the potential of business process metrics. Most of the proposed metrics were adapted from the software engineering domain. Following the software engineering categorization, we present these quality metrics divided into the three Cs categories: Coupling, Cohesion and Complexity.

2.1 Complexity metrics

Informally, *complexity* measures the simplicity and understandability of a design. From this angle, [CMN+06] and [GL06], for instance, adapted McCabe's cyclomatic number [McC76] as a complexity metric for business processes called *CFC* (Control Flow Complexity). This metric evaluates the complexity introduced by the XOR, OR, and AND split constructs. The main idea behind it is the number of mental states that have to be considered when a designer develops a process. Every split in the model adds to the number of possible decisions as follows:

- Every AND-split in a model adds 1 to the *CFC* metric of the model.
- Each XOR-split with n outgoing transitions adds n to the *CFC* metric of the model.

– An OR-split with n outgoing transitions adds $2^n - 1$ to the *CFC* metric of the model.

In this way, the *CFC* of a business process *P* is calculated as follows:

$$CFC(P) = \sum_{C \in P,\ C \text{ is } AND-split} CFC(c) + \sum_{C \in P,\ C \text{ is } OR-split} CFC(c) + \sum_{C \in P,\ C \text{ is } XOR-split} CFC(c) \quad (1)$$

The greater the value of the *CFC* is, the greater the overall architectural complexity of a process is.

In addition to *CFC*, the authors in [CMN+06] propose to adapt the Halstead measures [KAH+97]. The obtained metrics are called Halstead-based Process Complexity measures (HPC). They measure the length *N*, the volume *V* and the difficulty *D* of a process as follows:

$$\text{Process Length: } N = n_1 * \log_2(n_1) + n_2 * \log_2(n_2) \quad (2)$$

$$\text{Process Volume: } V = (N_1 + N_2) * \log_2(n_1 + n_2) \quad (3)$$

$$\text{Process Difficulty: } D = (n_1 / 2) * (N_2 / n_2) \quad (4)$$

where: n_1 is the number of unique activities, splits and joins, and control-flow elements of a business process; n_2 is the number of unique data variables manipulated by the process and its activities; and N_1 and N_2 are respectively the total number of elements and data occurrences. According to the authors, these measures do not require in-depth analysis of process structures, they can predict rate of errors and maintenance effort, they are simple to calculate and they can be used for most process modeling languages.

The metric of Henry and Kafura [HK81] was also adapted to give the Interface Complexity (*IC*) [CMN+06]. It is calculated for each activity as follows:

$$IC = length * (number\ of\ inputs * number\ of\ outputs)^2 \quad (5)$$

where the length of an activity is defined depending on weather it is represented as a black box or a white box: a black box activity gives information only about its interface; thus, its length is assumed to be equal to 1. On the other hand, the length of a white box activity is equal to the number of its tasks. The advantage of the *IC* metric is that it takes into account data-driven processes [CMN+06].

Also considering activities as white boxes, other researchers define the nesting depth (*ND*) of an activity [GL06] as the number of decisions in the control flow necessary to reach this activity. Accordingly, maximum nesting depth and mean nesting depth are defined for measuring nesting depth which influences the overall complexity of a model: A high nesting depth implies a high complexity.

Furthermore, the cyclicity metric (*CYC*) counts the ratio of the number of nodes (activities and gateways) in a Cycle (*NNC*) to the total number of nodes (*TNN*) in the considered process [Me08]:

$$CYC = NNC / TNN \quad (6)$$

The modularity of business process models [GL06] was been also quantified by the *Modularization* metric which is defined as follow:

$$Modularization=(fan\text{-}in * fan\text{-}out)^2 \quad \textbf{(7)}$$

where fan-in is a count of all sub-processes that call a given sub-process and fan-out is a count of all sub-processes that are called from the sub-process under investigation. In fact, dividing a BPM into modular sub-processes can not only help to make the BPM easier to understand, but it can also lead to smaller, reusable models if modularization is used in a reasonable way [GL06].

The number of activities (tasks and sub-processes) *(NOA)* and the number of activities and control-flow elements *(NOAC)* in a process are two additional complexity metrics adapting the software engineering *LOC* (line of code) metric. They are simple and treat a process activity as a program statement [CMN+06].

Moreover, other metrics were adapted from the graph theory. For example, the authors in [CMN+06] define the Coefficient of Network Complexity *(CNC)* which is the number of arcs divided by the number of nodes (activities, joins, and splits) in a model.

For a detailed evaluation of complexity of a business model, Mendling et al. [Me08] have proposed a density metric inspired by social network analysis. They have considered minimum and maximum number of arcs for a given set of nodes. While the significance of density is promising, the experiment they carried out reveals that there are further metrics needed in addition to density.

Beside the above metrics, a number of complexity metrics were proposed in [RRG+06] using the specification 1.1 of BPMN [OMG04]. These metrics have intuitive formulae; due to space limitations, the reader is referred to [RRG+06] for the detailed definitions.

In addition, it is worth mentioning that several complexity metrics were summarized in [AKW08] and classified into five sub-categories: size, complexity, structure, comprehensiveness and modularization. Moreover, Cardoso proposes in [Ca05] another classification of complexity metrics. He distinguishes four categories: activity complexity, control flow complexity, data flow complexity and resource complexity.

2.2 Coupling metrics

Coupling is defined as being the strength of interconnections between activities in a process model. So far, only a small number of researchers have developed coupling metrics for business process quality evaluation.

The authors in [VCR07] define coupling as being the number of interconnections between activities in a process model. The degree of coupling depends both on how complicated the connections are, and on the type of connections between activities (AND, OR, XOR). The coupling metric CP given by (8) counts all pairs of activities in a process model that are connected to each other [VCR07]:

$$CP = \frac{\sum_{t_1,t_2 \in T} connected(t_1,t_2)}{|T| * (|T| - 1)} \quad (8)$$

where t_1 and t_2 are elements of the set of activities T in the BPM, m is the number of ingoing arcs to the connector, n is the number of outgoing arcs and connected (t_1, t_1) is a function that gives a weight for each branch between two activities t_1 and t_2 according to the connection type. This weight is based on the probability that the particular branch is executed. The weights for each branch can then be determined as follows:

- AND is the strongest binder, because every branch of it is followed in 100% of the cases. Thus, the probability of following a particular branch is 1.
- XOR is the weakest binder, because in any case only one of the branches is followed. Thus, the probability of following a particular branch is $1/(m*n)$.
- OR must have a weight in between the AND and XOR, since one does not know upfront how many of the branches will be followed. The weight of an arc therefore depends on the probability that the arc is followed. So, there are $(2n-1)$ $(2m-1)$ combinations of arcs that can be followed. One of them is the AND situation, for which the probability then is $1/$ $(2n-1)$ $(2m-1)$. All the other combinations get the weight of an XOR.

Thus, in total, the weight of an arc going from one activity to another activity via an OR connector can be calculated by [18]:

$$1/((2n-1)(2m-1))+((2n-1)(2m-1)-1)/((2n-1)(2m-1))(1/(m.\ n)) \qquad (9)$$

Note that this metric takes into account only control flow and does not deal with data. Another coupling metric is defined in [RV04], which includes data flow and counts the number of related activities for each activity. An activity is connected to another one if and only if they share one or more information elements. First, the average coupling is determined by adding up the number of connections for all activities and dividing this number by the total number of activities. To get a relative score for this metric, the average coupling is divided by the maximal number of coupling, *i.e.* the number of activities minus one.

2.3 Cohesion metrics

Cohesion metrics measure the coherence within parts of a BPM. So far, there is a very little work dealing with cohesion metrics for business processes available. The most significant one is that of Reijers and Vanderfeesten [RV04] who adapted the cohesion metric as follows: The cohesion of an activity is the product of both the relation and information cohesion. The relation cohesion quantifies how much different operations within one activity are related. It determines for each operation of an activity with how many other operations it overlaps by sharing an input or output. On the other hand, the information cohesion focuses on all information elements that are used either as input or as output by any operation within this activity. It determines how many information elements are used more than once in proportion to all the information elements used. It counts all different information elements that appear in the intersection of a pair of operations, considering all pairs. This number is divided by the total number of information elements in the activity.

In [VRM08], the authors define the cross connectivity metric (CC) which quantifies the ease of understanding and the interplay of any pair of model elements. The term 'Cross-

Connectivity' is chosen because the strength of connections between nodes is considered across all nodes in the model. As a result, CC expresses the sum of the connectivity between all pairs of nodes in a process model, relative to the theoretical maximum number of paths between all nodes.

In summary, a great number of metrics are proposed in the literature. The only classification provided for them is based on the purpose of their use which is measuring complexity, coupling or cohesion. Evidently, not all the proposed metrics consider the designed business process from a single perspective. In fact, this might hinder their usage. In the next section, first, we will organize BPM concepts in terms of their pertinent perspective; for this, we use the meta-model of the standard notation BPMN [OMG04]. Secondly, we will use this organization to classify the metrics according to different BP perspectives.

3 A quality metric framework for BPMN

3.1 Modeling perspectives in BPMN

The representation of models from different perspectives is a vital modeling approach to apprehend for instance the model complexity [FGH+94]. A particular perspective can be designed based on analytical criteria or subjective needs [Pe07]. For instance, a model must be capable of providing various information elements such as what activities the process comprises, who is performing these activities, when and where are these activities performed, how and why are they executed, and what data elements do they manipulate [GG01].

To represent such information, Curtis et al. propose four perspectives [CKO92]: functional, behavioral, organizational, and informational. These perspectives have been widely adopted by several researches. For instance, in [Ja94] the authors propose an approach of perspective oriented process modeling called POPM which can be used for any (basic) process modeling language.

The *functional* perspective represents what process elements (*i.e.*, activity, sub-process and tasks) are being performed, and what flows of informational entities (*e.g.*, data, artifacts, products) are relevant to these process elements [CKO92]. Given this definition, the BPMN main concept that reflects the functional perspective is *Activity*. Hence, as illustrated in Fig. 1, the BPMN meta-model part that can be used to model this perspective regroups those meta-classes related to (inheriting from) the activity meta-class.

On the other hand, the *behavioral* perspective represents *when* process elements are performed (*e.g.,* in sequence), and *how* they are performed through feedback loops, iteration, complex decision- making conditions, entry and exit criteria, and so forth [CKO92]. Therefore, the base meta-classes in this perspective are *Gateway*, *FlowNode*, *SequenceFlow*, and the elements in the package *Collaboration* from the *Analysis Model* of BPMN. As for the *organizational* perspective, it represents *where* and *by whom* process elements are performed, the physical communication mechanisms used for entity transfers, and the physical media and locations used for storing entities [LK06].

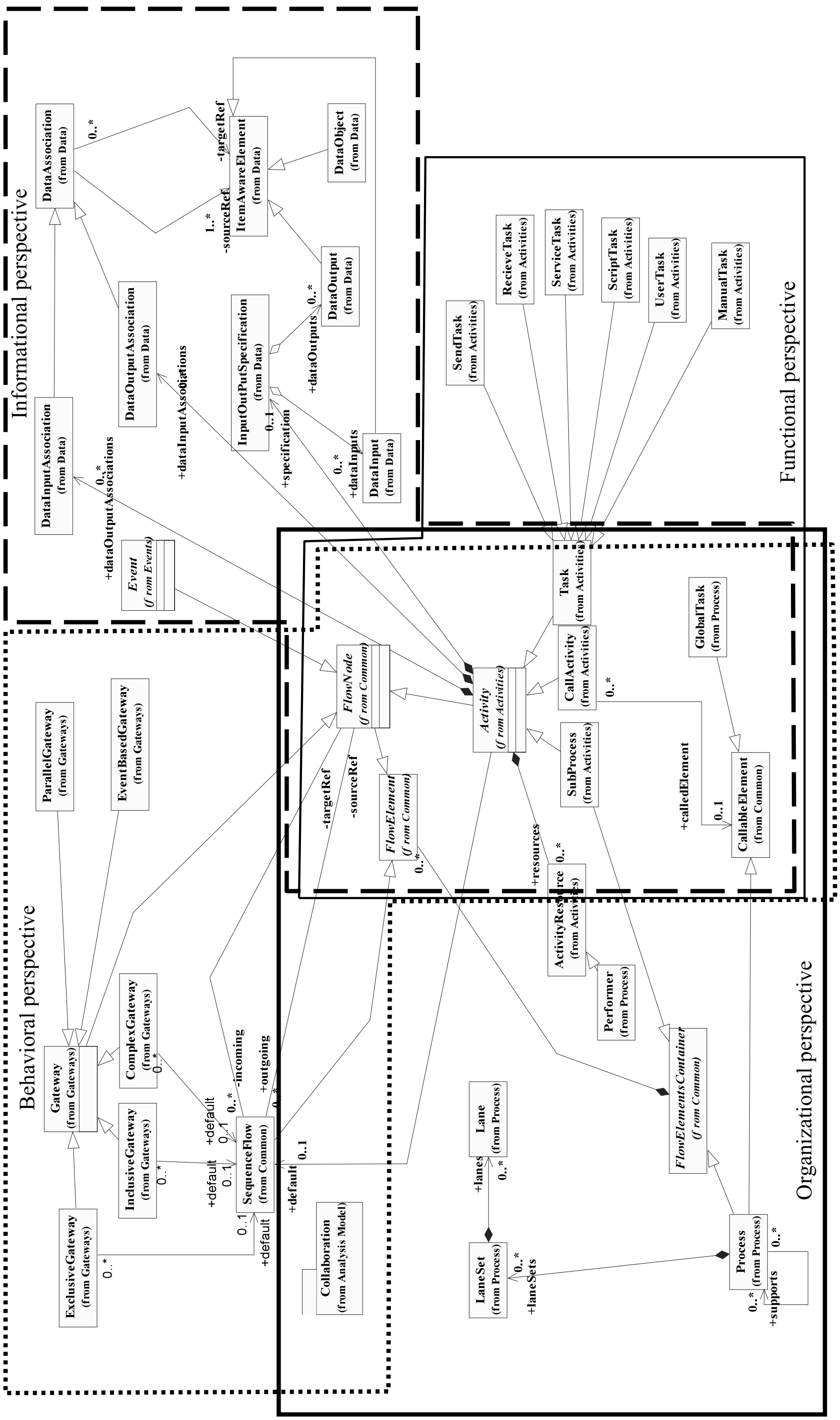

Figure 1: Perspective elements in the BPMN meta-model

Finally, the *informational* perspective represents the informational entities produced or manipulated by a process; these entities include data, artifacts, products (intermediate and end), and objects; this perspective includes both the structure of informational entities and the relationships among them [LK06]. Hence, as illustrated in the corresponding package (Fig. 1), the informational perspective is represented in terms of data and event related classes (*e.g.*, DataOutput, Event, etc.).

3.2 A classification framework

The metric classification framework which we propose is given in Fig. 2. A metric is characterized by its algorithm and the attribute *derivation* to indicate whether the metric is a derived one. Indeed, each metric may be either a direct or an indirect (i.e., a derived) metric. According to the standard 1061 [KB04], a direct (or fundamental) metric depends only on one model element. For example, *NL* (Number of lanes) is a direct metric, while *CFC* (see section 2) is derived. A direct metric provides a direct idea on the quality of one BPM element and on the interpretation of the metric value, while a derived metric captures information about more than one model element. It gives a measured value that gives indirectly a general/an aggregated view of the quality of the BPM.

The association concerns between the classes Metric and BaseElement defines those elements of BPMN (version 2.0) which are considered by this metric. For example the CFC metric must be linked to the element sequence flow. The class Metric is also linked to the class Dimension through the association informs about which associates each metric with the quality dimensions about which the metric informs. For example, the CFC metric must be combined with the dimensions comprehension and maintainability.

Moreover, Fig. 2 shows possible specializations of the class *Metric* which correspond to the three metrics categories: complexity, coupling and cohesion. The property *incomplete* tagging the generalization/ specialization relationship means that other metric categories may be added.

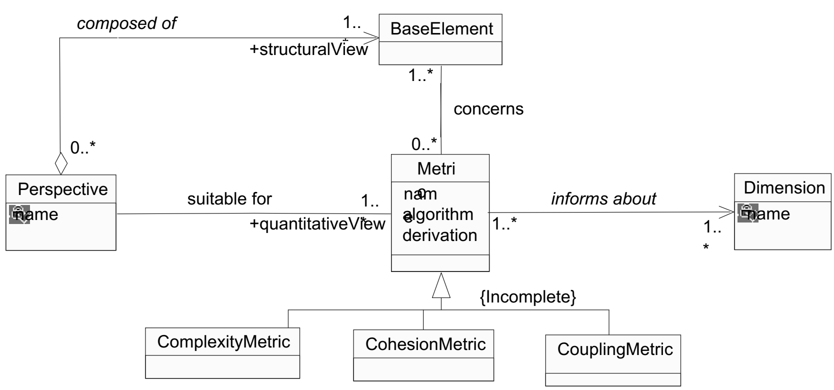

Figure 2: Quality metrics classification framework.

Finally, the third association of class *Metric* links it to the class *Perspective*. It establishes a link between each metric and all perspectives in which it may be calculated. From a perspective view point, the collection of metrics associated with it constitutes a quantitative view of that perspective.

4 BPMN Quality Tool

Based on the classification framework presented in Section 4, we have developed a tool for assessing quality of business process models named *BPMN Quality*. It implements all the metrics defined in the literature.

BPMN Quality is developed in JAVA and is composed essentially of four modules (see Fig. 3): a BPM elements extractor, perspectives constructor, metrics calculator and an interpreter.

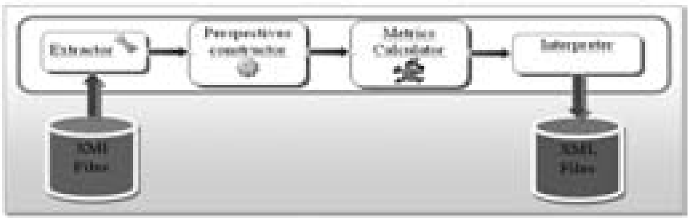

Figure 3: Functional architecture of BPMN quality.

The *extractor* receives as input a BPM transformed into XMI [10]. This transformation aims to obtain a BPM in a standard exchange format. The information extracted by this module involves all elements contained in the BPM. The use of the standard ensures that our tool can be integrated within any other modeling tool that supports this standard.
The information provided by the *extractor* is passed to the perspectives *constructor*. By taking into account the perspective chosen by the user, this module generates from the BPM data, the tree containing all elements which belong to this perspective.

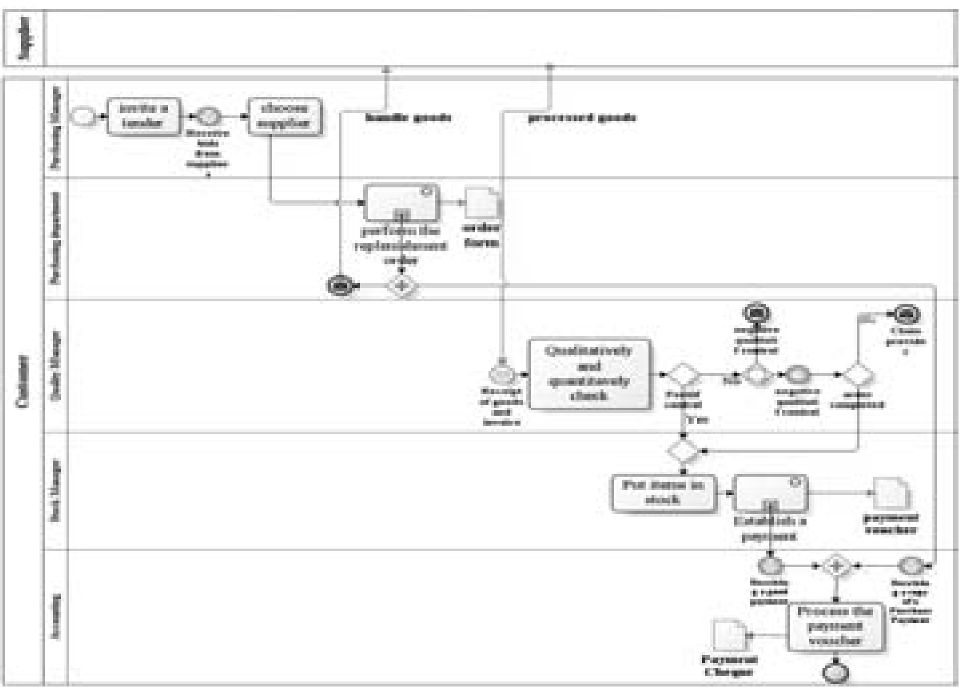

Figure 4: Supply management process.

The metric *calculator* is a module that implements all the metrics calculation algorithms. It uses the information provided by the perspectives *constructor* and the category of metric chosen by the user in order to calculate and display metrics values corresponding to these choices and saves them as a XML file. The structure of this file is the DTD issued from our classification framework.

In order to illustrate the functioning of the calculator module, we apply it to the *supply management process* model of Fig. 4. If the analyst selects the 'Complexity' metric category, the perspective type *Organizational* and the *Derived* metric type, the list of metrics which is associated to these levels will be displayed. Fig. 5 shows the interface associated with this choice and the obtained metrics values.

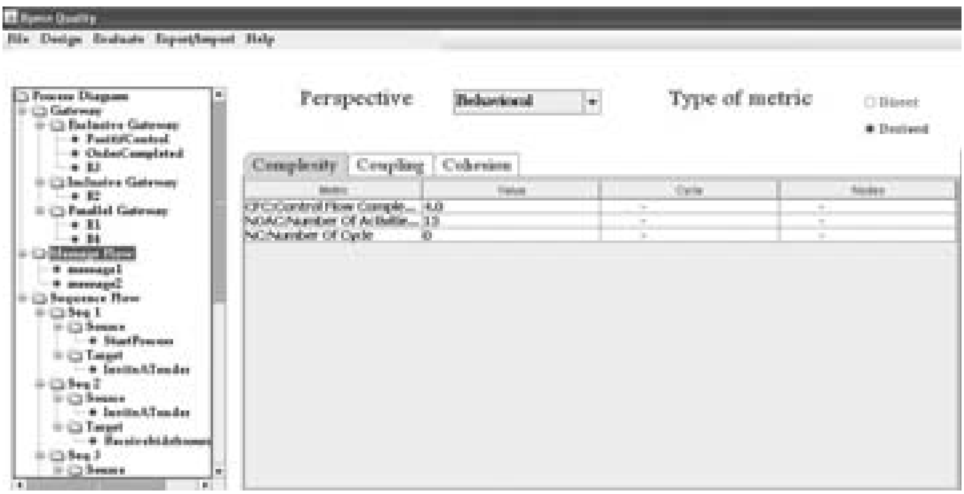

Figure 5: Interface associated with the choice of the analyst.

On the other hand, the *interpreter* module compares the obtained results to threshold values of metrics introduced by the user. According to the quality dimensions associated with the chosen metrics, the *interpreter* gives an evaluation of the quality of the business process under analysis. The comparison process is carried out as follows:

– Through the interface presented in Fig. 6, the *interpreter* displays for each of the quality dimensions maintainability, comprehension, reuse and redesign the associated metrics according to our classification framework (see Fig. 2). The relationships between a quality dimension and the metrics upon which it depends are deduced from literature (cf., [CMN+06] [GL06] [VCM+07]). Then the designer can choose one or more metrics that have to be included in the model.

– The *interpreter* proposes a priority order between the chosen metrics. This order is deduced from the researches presented in literature [CMN+06] [GL06] [VCM+07] based on the relationship between the metrics and the dimensions. In addition, it reflects the fact that a metric is used more than another in order to evaluate the BPM quality for the considered dimension. However, the order proposed by the *interpreter* can be redefined by the designer.

– The *interpreter* allows the user to introduce for each metric a threshold that reflects its optimal value. This value may be found as a result of empirical studies.

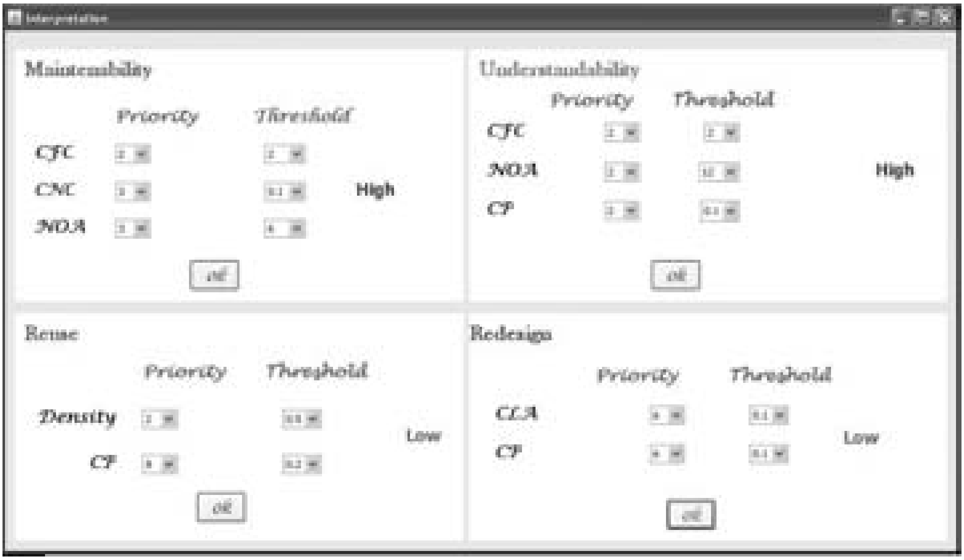

Figure 6: Results interpretation.

- If all necessary values are provided by the user, the *interpreter* computes for each quality dimension D_k the sum σ_k of the pertinent metric values computed by the *calculator* module. The sum is weighted by the metric priorities. Formally, σ_k is calculated as follows:
  - Let $m_1, m_2, \ldots, m_n$ be the metrics associated to a given quality dimension and $p_1, p_2, \ldots, p_n$ the assigned priorities (a high value corresponds to a high priority). The weight α_i of each metric is calculated by the following formula:

$$\alpha_i = \frac{p_i}{\sum_{i=1}^{n} p_i} \qquad (9)$$

  - Let $v_1, \ldots, v_n$ be the metrics values determined by the *calculator* module. Then:

$$\sigma_k = \sum_{i=1}^{n} \alpha_i v_i \qquad (10)$$

- After computing the weighted sum, the *interpreter* computes for the same quality dimension D_k the sum $\overline{\sigma}_k$ of the metrics thresholds values which are fixed by the designer. These values are weighted by the metric priorities α_i. Formally, $\overline{\sigma}_k$ is calculated as follows:
  - Let $t_1, \ldots, t_n$ the thresholds associated respectively by the designer to the metrics $m_1, \ldots, m_n$. Then:

$$\overline{\sigma}_k = \sum_{i=1}^{n} \alpha_i t_i \qquad (11)$$

– Finally the comparison between σ_k and $\overline{\sigma}_k$ provides an assessment (*high*, *medium* or *low*) of the quality dimension D_k. Fig. 6 shows the interpretation of the metric values obtained for the dimensions maintainability, redesign, reuse, and understandability.

5 Conclusion

In this paper, we have presented *BPMN Quality*, a tool for assessing quality of business process models. This tool implements a classification framework organizing in three-levels the quality metrics of BPM. At the first level, the metric belongs to one of three categories: complexity, coupling and cohesion. At the second level, for each category, we associate metrics to perspectives (functional, organizational, informational and behavioral). Thanks to this second level, our framework helps the designer to select the suitable subset of quality metrics dealing with his/her perspective. At the third level, we classify quality metrics into direct and indirect (derived). On the one hand, direct metrics give a direct idea on the quality of BPM; on the other hand, derived metrics provide an aggregate value that gives indirectly a general view on the BPM quality. It is important to note that our framework is extensible, so further perspectives and metric types may be considered.

Our future work focuses on adding another plug-ins to *BPMN Quality* such as an optimization module in order to alert the designer of potential impacts of their decisions upon the various perspectives.

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Flexible Workflows for an Energy-Oriented Product Development Process[1]

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Abstract: Product development processes are flexible and dynamic in nature. In this domain, workflows are commonly used for representing business processes in change management or for document management. The product development process itself can hardly be represented by a business process that is defined in a design phase and fixed during runtime. However, the workflow technique can be extended by concepts for flexible workflows. Many workflow management systems now provide solutions for flexible process changes. In this article, hierarchical workflows and dynamically selectable sub-workflows are introduced to enable a flexible workflow execution on a standard workflow management system. As proof of concept flexible workflows are applied to an energy-oriented product development process.

1 Introduction

Product development processes are creative and highly-dynamic processes controlled by the design engineers. In contrast, business processes have traditionally been seen as well-structured and fixed. However, the business world changes this view and the optimization of processes as well as quick adaptation to customers' needs become requirements. Workflows that are used to represent such business processes need to allow flexible modeling. The workflow management system (the configuration and executing software system of workflows) has to provide capabilities to evolve workflow definitions as well as to apply ad-hoc changes to workflow instances. In this article, we investigate how these concepts of workflows for business processes can be applied to product development processes.

Research (e.g., [HS08]) has shown that it is impractical to model the whole product development process as a single workflow. Instead, product development utilizes concepts like product data management to organize product related data and documents. Workflows are embedded to organize common activities for document management and

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to track product changes or configurations. These processes are very similar to business processes of other domains. The actual product development can be seen as mental processes of the engineers. Design theories and methodologies try to capture, structure, and document these processes, for example in the VDI-guideline 2221 ([VDI93]), the cognitive science based approach by [Ger90], or its extension in [Col07]. For this article, the property-driven design by [WD03] is exploited. Instead of a predefined business process, product development is described by repeated actions to analyze the product requirements, to synthesize a new product design, and to verify the expected product functionality. Each step requires engineers to apply methods of different engineering domains, mainly based on their expertise and with certain design goals in mind. Usually, these methods involve computer-aided tools to calculate, optimize, or simulate technical and economic product data.

In recent years the design goal "energy-efficiency" for products has become more important. The need to adapt the product development process to energy-efficiency, as proposed by [NFP+09], can be supported by combining the property-driven design approach with explicit, flexible workflows to express the product development process. An obvious advantage of this approach is the possibility of documentation and visualization of the development process. The process is reproducible and overall strategies for product development can be applied. The design goal "energy-efficiency" can be supported by invoking simulation or optimization tools to predict and reduce the energy usage of the final product within the current design context.

This article proposes to model the property-driven design approach by a combination of hierarchical workflows and flexible sub-workflows. This approach utilizes sub-workflows to represent and refine individual analysis, synthesis, and verification activities. To reflect the dynamic flexibility of product development processes, changes can not only be applied during workflow definition, but also while a workflow instance is running. Therefore, recent efforts to systematize flexible workflows, e.g., by change patterns [WRR08] or flexibility patterns [MvdAR08], are considered. Especially, the concept to dynamically select sub-workflows during workflow execution is promising for an implementation of the property-driven design. A new dynamic-selection pattern is inferred from existing flexible workflow concepts that supports parallel execution of sub-workflows in the product development process. As a result, requirements for implementing these concepts in a standard workflow management system are discussed.

The article is organized as follows: Section 2 describes a dynamic-selection pattern based on hierarchical workflows and existing flexible workflow concepts. The workflow technique is applied to a product development process for energy-efficient products in Sect. 3. In Sect. 4, the implementation of the workflow extension with a standard workflow management system is discussed. Section 5 considers related work, and Sect. 6 concludes the article.

2 Hierarchical and flexible workflows

In this section, an overview on business processes as well as workflows is given. Hierarchical workflows and the concept of flexibility for workflows are summarized. Also, a dynamic-selection pattern is introduced that forms the basis for adopting the workflow technology to express the property-driven design approach.

2.1 Hierarchical workflows

Business processes focus on processing business objects in a structured way. The "tasks" (work items) are primarily executed by the users. In the business domain, a *business process* describes an organizational process in an enterprise, not an executable program. Thus, the informal business process description has to be transformed into a *workflow* which can be executed by a workflow engine, e.g., defined by the workflow reference model of the Workflow Management Coalition[2]. Each workflow consists of *activities* (or atomic tasks) that can be processed automatically or with human interaction. Designated start and end tasks, and transitions between activities imply an explicit order of the execution sequence. Special control structures are available to model parallel activities (fork nodes), alternative paths (decision nodes), and join activities (join nodes).

For an additional structuring of workflows, tasks can be organized as sub-workflows. These are fragments of a workflow that can be viewed as separate workflows themselves. In the main workflow, the sub-workflow is replaced by a single activity which transfers the workflow execution to the sub-workflow and returns to the main workflow after the sub-workflow has been finished. This hierarchical structuring of workflows has two advantages. First, repeated fragments of the workflow can be replaced by a single sub-workflow for better maintenance. Second, the workflow can be displayed in several levels of detail. A large, complex workflow can be illustrated by an overall view where no details are visible. Sub-workflows describe specific activities or other sub-workflows and therefore add an additional level of detail to the workflow (see Fig. 2). Human readability of workflows is significantly improved by introducing hierarchical workflows, as for example pointed out by [RM08]. As shown in [TRC+08], business activities like approval, decision making, or notification can be expressed as sub-workflows and can be used as building blocks for the workflow definition.

As a result, a workflow definition by means of hierarchical structures can be introduced:

- The workflow consists of a *main workflow* with an explicit start and end node,
- defines n sub-workflow definitions in a partial order,
- contains additional control structures (loops, forks, joins, etc.), and
- shows the workflow with a detail level of 0.

If all sub-workflows contain exactly one activity, the main workflow is completely defined, otherwise the definition of levels given above is applied recursively to the sub-workflow. Each sub-workflow in the hierarchical structure exposes additional details to

[2] http://www.wfmc.org/

the workflow representation. If a calling workflow shows detail level *l*, each new sub-workflow called from this workflow has level *l+1*.

In standard workflow languages, each activity in the main workflow can represent exactly one sub-workflow definition. The workflow patterns by [vdAtHKB03] provide a way to extend this behavior. One of these workflow patterns, called WCP-15 in [vdAtHKB03], creates multiple instances of a task, not knowing the number of instances prior to runtime. Another workflow pattern, WCP-36, specifies the completion condition of the tasks: Either all running tasks have to finish or an explicit completion criterion is defined to trigger the next task in the workflow.

In this article, pattern WCP-15 and WCP-36 are extended to activate multiple, not necessarily different sub-workflow definitions per activity. This means that an *1:m* relationship between activity and sub-workflows can be established by splitting the main workflow into concurrently executing sub-workflow instances. Additionally, multiple instances of the same sub-workflow definition may be instantiated based on runtime conditions. The main activity is completed only if some (partial join) or all sub-workflow instances (join) are finished. Instances not completed are aborted and rolled back.

A major issue when implementing the described pattern is the synchronization of concurrently running sub-workflows. The sub-workflows are executed in form of parallel threads that are not coordinated with each other. They may be all started at different times after the main activity is triggered. The sub-workflows are not ordered in their execution. None of the workflow pattern of [vdAtHKB03] describes the behavior needed for a parallel synchronized execution of sub-workflows. A possible solution can be to add flexibility to workflows. In the next section, the discussed extension for hierarchical structures is combined with flexible workflow constructs to introduce a new dynamic-selection pattern.

2.2 Adding flexibility to hierarchical workflows

Introducing flexibility in workflows can help to enhance the expressiveness of hierarchical workflows by introducing incomplete descriptions or templates that are specified at runtime. Template definitions embody several cases which otherwise have to be modeled explicitly. In hierarchical workflows, a selection of sub-workflows is enabled at runtime when a certain template activity is reached. This behavior is described by the *Late selection pattern (PP1)* in [WRR08] in three different versions: The selection is based on a user decision, predefined rules filter available selections, but the user decides which one is taken, or the predefined rules decide autonomously. The last version is described by the *worklet* concept of [AtHEvdA06].

Worklets describe a dynamic approach to specify hierarchical workflows. A parent process captures an entire workflow. It arranges a number of activities where each activity has a number of worklets attached. Worklets are single sub-workflows kept in a repository. When the parent process is running and a certain activity is enabled, a selection rule automatically chooses an appropriate worklet and integrates it into the parent workflow

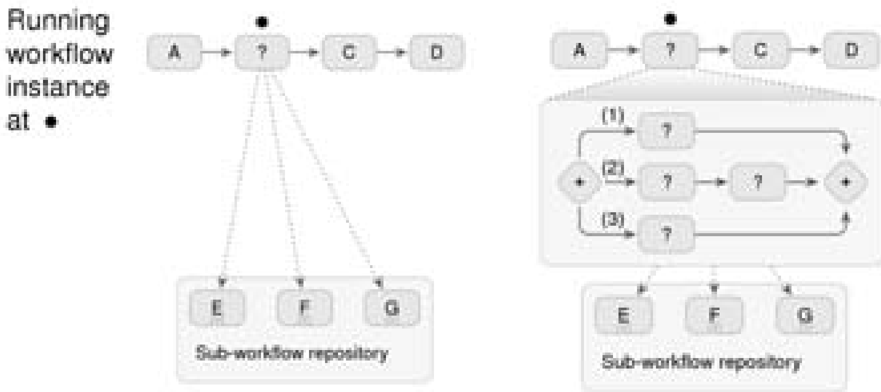

Figure 1: Comparison of late selection of sub-workflows with worklets (left) with an extension where sub-workflows can be arranged at runtime and executed concurrently (right)

enactment. By adding new worklets to the repository changes to workflow definitions can be evolved (see Fig. 1, left).

Worklets allow a dynamic selection of sub-workflows, but neither the coordination of multiple worklets nor the parallel execution is included. These two aspects are addressed in the change patterns of [WRR08]: *Late composition (PP3)* and *Multiple instance activity (PP4)*. With the late composition pattern a given number of sub-workflows can be arranged at runtime. The pattern PP4 supports multiple instances of sub-workflows.

As the existing patterns describe only parts of the needed functionality, a new dynamic selection pattern is introduced. This pattern considers the runtime composition as a new worklet. The user and/or the system chooses a number of sub-workflows that are arranged as a worklet to be called dynamically in the main workflow (see Fig. 1, right (2)). Further flexibility can be achieved by merging late composition with multiple instances (see Fig. 1, right (1) and (3)). This results in a new dynamic-selection pattern that can instantiate multiple worklets and execute them concurrently. As a consequence, parallel execution of dynamically selectable sub-workflows is supported and these sub-workflows can be synchronized with each other.

3 Applying hierarchical and flexible workflows to the product development process

The result of the product development process is a specification to manufacture the product. Domain experts use their domain knowledge of product developing methods and tools to infer product structures from given requirements. A product development process to accomplish this is described in the property-driven design (PDD) approach which uses loops of analysis of the current product behavior, synthesis of new product structures, and verification of the intended product behavior (a special form of analysis). For each design iteration, engineers have to choose the most suitable methods and tools.

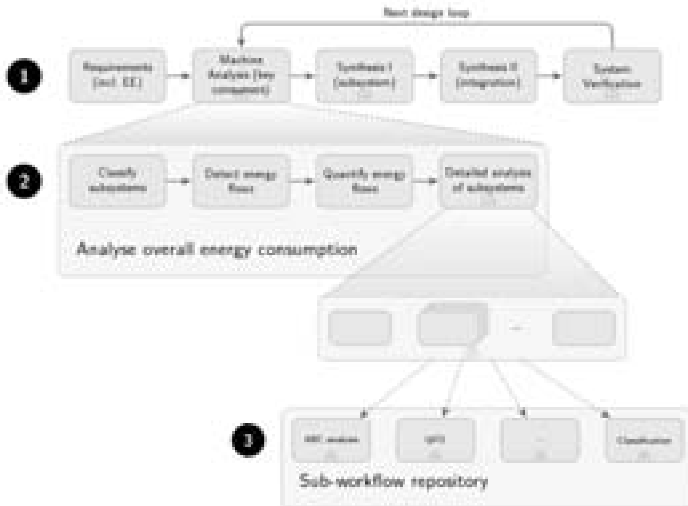

Figure 2: Hierarchical workflow model for an energy-oriented product development process in the PDD approach

Even the number of iterations may vary according to the product's complexity, the type of development, or external conditions. In this section, the principles of hierarchical, flexible workflows are applied to this approach.

A hierarchical workflow with a main workflow and sub-workflows as discussed in Sect. 2 can be exploited to model a product development process with the PDD approach. A main workflow describes the analysis-synthesis-design loop of the PDD approach. Individual methods used by engineers are defined as sub-workflows. The dynamic-selection pattern shown in Fig. 1 (right) allows the engineers to choose the most suitable method.

To further illustrate the approach, a product development process for energy-oriented product designs, described in [NFP+09], is taken as an example. The major design goal for such an energy-oriented development process is to optimize the energy consumption during the product's life cycle, not only for manufacturing, but also for operation and recycling. Though the functionality of the product has to be guaranteed, particular product development methods and tools are incorporated to save energy throughout the product life. Additionally, the costs of the product have to be considered. With hierarchical workflows this process can be modeled as shown in Fig. 2.

The main workflow (1) describes the basic activities according the PDD process: *Analysis*, *Synthesis I+II*, and *Verification*. They are executed in a loop. For energy optimization, individual activities for analysis, synthesis, and verification can be described by sub-workflows. In Fig. 2, the *Machine Analysis* step, which consists of the identification of energy flows in similar products, is shown in detail (2). By finding key energy consumers, the engineers can choose which subsystems of the product should be improved for the new design. For each subsystem, energy flows have to be detected and quantified.

The results are analyzed by engineers and the key consumers are identified. For this analysis, multiple engineering methods need to be made available in form of dynamically selectable sub-workflows (3). The engineers may decide to subdivide energy consumers into classes, e.g., of high energy consumers and low energy consumers, with ABC analysis using the method first applied by [Par71]. Also the engineers can correlate product components with given quality measures by quality function deployment (QFD) [Gra06]. Further classification methods are available. The engineers may use one or more of these analysis methods, either in parallel or one after another. Sub-workflows can be categorized with automatic rules to allow only valid choices of sub-workflows in the current design context (e.g., only analysis sub-workflows).

The following steps in the main workflow (1) in Fig. 2 use the analysis results to synthesize new, energy-optimized subsystems. These steps are organized in similar sub-workflows as shown for the machine analysis. The new design results will be integrated into the product. Finally, the achieved energy-efficiency has to be verified as well as the product's functionality and cost. Results are taken as input for the next design iteration. Although the sequence of actions in the main workflow is fixed, individual sub-workflows differ according to the current development context and the design engineers' needs. Indeed, design engineers may apply various calculation and simulation methods in form of sub-workflows per activity, before they proceed.

In a common product development scenario, multiple engineers work concurrently on different subsystems of the product. Therefore, the corresponding sub-workflows need to be executed concurrently, for example per subsystem or engineer. To coordinate the development activities, PDD provides the *Synthesis II* step, in which modified subsystems are integrated into the entire product. As a consequence, this activity corresponds to a synchronization construct in the workflow.

4 IT support for hierarchical and flexible workflows

This section examines requirements for an IT system to implement the hierarchical and flexible workflows presented in Sect. 2. The solution proposed is based on the JBoss platform[3] that already includes integration components, like the JBoss ESB (enterprise service bus) and the workflow engine jBPM. Utilizing existing components, a service-oriented IT system is constructed that integrates hierarchical workflows for product development according to the PDD approach.

4.1 A workflow-based software architecture

The hierarchical, flexible workflows described can be implemented with a service-oriented approach. The basic idea of services is to modularize functionalities and make them available in a uniform way. When applying this concept to workflows, services with nested workflows can be expressed. If workflows contain activities that realize

[3] http://www.jboss.org

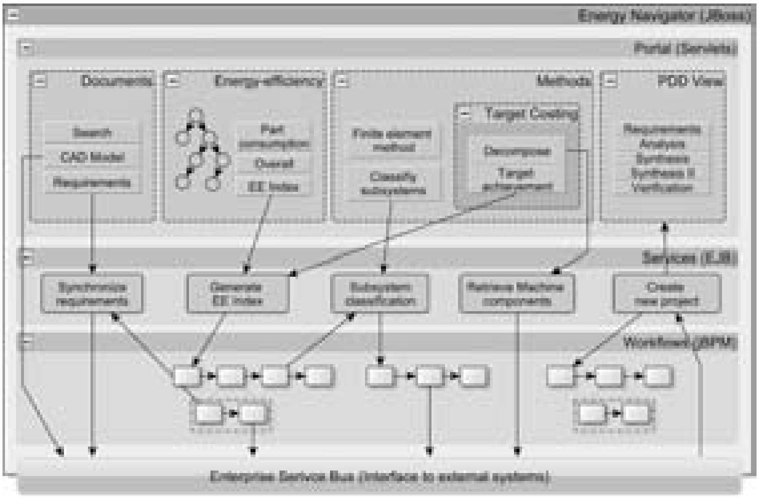

Figure 3: IT System for implementing an energy-oriented product development process

service calls, a hierarchical workflow is formed. This concept is introduced by [vAtH+09] and named by the term *flexibility as a service*. In their implementation, flexible workflow technology, like worklets, is embedded in services. The YAWL workflow engine [vt03] acts as an intermediate layer to orchestrate the services, and is extended with an interface to the flexible workflow services.

The implementation concept described in this article uses the *flexibility as a service*-approach, but instead of extending the workflow engine, a workflow service integration interface is provided by integrating an enterprise service bus (ESB). This software component provides necessary means for a service-oriented IT system and a three-layered software architecture is created as shown in Fig. 3.

The architecture consists of a base layer implementing the workflow technology with the jBPM workflow engine (*Workflows*). The workflows describe human activities and system activities to guide the execution of the product development process. The next layer is a service layer that can nest the workflows and provides a uniform interface to external systems (*Services*). An *Enterprise Service Bus* (ESB) is incorporated as an integration component. In the energy-oriented product development, relevant data needs to be collected from various IT systems and should be made available to the engineers. In the machine analysis, for example, this data may consist of experimental measurements or estimations about energy consumptions during product manufacturing or operation. An ESB provides a wide range of standardized interfaces to connect the workflow management system to external systems storing this data (e.g., an enterprise resource planning system). The message-oriented communication in combination with the jBPM engine (see [JBo10]) can be used to call a service that starts the sub-workflow and continues the main workflow until a synchronization point is reached. Abilities to dynamically route and transform messages allow a simple integration of additional IT systems, for example an enterprise resource planning system. In summary, external calls are made available as services to create a uniform service layer for workflow calls and system calls.

A user layer is the third layer in the software architecture (*Portal*). It enables the engineer to interact with the system. The user can view the current development process and the tasks assigned. The user interface allows the engineer to select and start the sub-workflows representing valid methods in the current design context. Results of analysis and synthesis activities can be accessed in form of documents or in an energy-efficiency view. This view shows collected and aggregated energy data to provide the engineers with input for their development efforts and energy comparisons between different designs.

4.2 Flexible sub-workflow selection

The implementation concept proposed in Sect. 4.1 is realized in a standard workflow management system utilizing the workflow constructs provided by JPDL[4] and custom Java extensions supplied by the workflow engine jBPM.

The dynamic-selection pattern can be subdivided into several components. First, sub-workflows in form of services need to be queried from the service repository of the ESB. Then, a rule-based action will automatically preselect sub-workflows according to the current development step, like analysis or synthesis, or other criteria. Next, the filtered list of services is presented to the user, who has now the task to identify which one of the sub-workflows should be called. For the assignment, the user role needs to be taken into account, and only sub-workflows corresponding to this role should be presented. After the user has selected a sub-workflow, the sub-workflow is called asynchronously by splitting up the workflow execution into two paths. One path activates and registers the sub-workflow in a list of running sub-workflows. On the other path, a loop-back returns to the selection of available sub-workflows and a next sub-workflow can be started. Multiple activities can run in parallel until the user decides to continue to the next step in the main workflow, instead of selecting another sub-workflow. All running sub-workflows have to be finished or cancelled before continuing. To achieve this, the workflow execution is blocked until an event listener receives the signal of an empty list of running sub-workflows.

Exception handling for the dynamic-selection pattern needs to be addressed. In all cases, the user should be able to continue the main workflow. Hence, exception handling in the running sub-workflows should include a loop-back to the selection of available sub-workflows.

5 Related Work

There are two lines of related work. On the one hand, research concentrates on IT support for product development processes. The main purposes of this work are the integration of CAx systems and the management of product data. On the other hand, workflow management systems for general business processes have been developed with the claim

[4] http://www.jboss.org/jbpm

to be applicable to different domains. Such systems exploit quite different approaches to include flexible workflows.

In SIMNET, a workflow management system for engineering changes in a collaborative environment was developed [YGH04]. Workflows are used to coordinate communication between distributed teams or companies. The project concentrates on a distributed, evolving product model; concepts for flexible workflows are not discussed.

FORFLOW is a research program [JFJ+08] that focuses on cooperative processes in product development. It utilizes process management concepts and product development methodologies to model product development processes in general. The contribution is a workflow management system which provides flexibility through late composition of activities as described in the change pattern PP3 of [WRR08]. Given a number of activities with a partial order and an optimization strategy, a recommended execution order of the activities is calculated. Flexibility is addressed by allowing changes in the execution order, but not by introducing constructs to dynamically change the current workflow execution or adding additional activities at runtime.

Enterprise models are IT representations of processes, information, and resources in a company. An example for an enterprise modeling language is CIMOSA [BV99]. It provides behavioral rules (AND, OR and XOR) to compose sets of tasks. The OR construct allows the execution of one, several, or all tasks of a given set of tasks. In contrast to the approach shown, the composed tasks in CIMOSA have to be available at design time and are not provided via a repository that allows changes at runtime. Additionally, each task in the OR construct is executed at least once; a repeated task execution is not part of the construct.

The DECLARE framework [vPS09] provides a different approach to workflow definition than standard workflow management. Instead of defining a strict order of activities by control structures, constraints between activities are assigned. Hence, any order of activities that will not violate the constraints is allowed during workflow enactment. Product based workflows [VRv08] combine the declarative workflow concept with a tight integration of processes and data. It is an example for a data-driven process concept described also in other approaches, e.g. [MHHR06]. An executable workflow is automatically inferred from the product data model, related operations, and a design strategy, e.g., for cost or quality. Though the approach is based on a specific product data model, it cannot be used for a product development process starting with an empty product model.

YAWL is an expressive workflow language [vt03]. Worklets extend the YAWL workflow management system to support flexible sub-workflow selection by automatic rules [AtHEvdA06]. Though the principle of worklets is rather similar to the approach described in this article, the rule-based approach is not sufficient to express the dynamic choices in product development and to assist the engineers when making design decisions.

Another workflow management system for dynamic processes is ADEPT2 [RDR+09]. The system allows ad-hoc changes to running workflow instances and process schema evolution that can be propagated to workflow instances. Approaches are taken towards detection and prevention of deadlocks or errors during process changes. In ADEPT2 changes are applied through a separate workflow editor. The user is not actively sculpting the process herself or himself, as it is the case with dynamically selectable sub-workflows.

The described approaches contribute to model different aspects of the product development process with workflows, but none of them can be fully applied to the property-driven design methodology. In particular, workflow constructs that express the analysis-synthesis loops of PDD are necessary. Consequently, a new approach based on a combination of hierarchical structures with flexible workflows is chosen in the presented approach.

6 Conclusion

In this article, an approach for applying flexible workflow technologies to complex product development processes is presented. Using the property-driven design methodology for product development enables the modeling of the process with hierarchical workflow structures and dynamically selectable sub-workflows. When designing energy-efficient products such a systematic approach is required. Most of the product's energy consumption, e.g., in operation, is a consequence of design decisions made during product development. Hence, an explicit model of the product development process is necessary to which energy optimization strategies can be applied.

Special attention is put on flexible workflow techniques which are provided by the concept of a new dynamic-selection pattern. This pattern is meant to be implemented on a standard workflow system. The selection pattern supports a semi-automated sub-workflow selection, which is pre-filtered by the system, and allows the user to select sub-workflows according the current development activity. A key concept for this approach is to provide workflows as services.

The contribution of this article is an extension of existing flexible workflow concepts by a combination of hierarchical structures with flexible selection. The discussed pattern is applied to the product development process to express the dynamic and parallel activities when developing new products. In conclusion, the approach is exploited to implement an energy-oriented development process in an IT system that utilizes a service-oriented architecture.

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Selection of the Best Composite Web Service Based on Quality of Service

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Abstract: The paper proposes a general framework to composite Web services selection based on multicriteria evaluation. The proposed framework extends the Web services architecture by adding, in the registry, a new Multicriteria Evaluation Component (MEC) devoted to multicriteria evaluation. This additional component takes as input a set of composite Web services and a set of evaluation criteria and generates a set of recommended composite Web services. In addition to the description of the conceptual architecture of the formwork, the paper also proposes solutions to construct and evaluate composite web services. In order to show the feasibility of the proposed architecture, we have developed a prototype based on the open source jUDDI registry.

1 Introduction

Individual Web services are conceptually limited to relatively simple functionalities modeled through a collection of simple operations. However, for certain types of applications, it is necessary to combine a set of individual Web services to obtain more complex ones, called *composite* or *aggregated* Web services. One important issue within Web service composition is related to the selection of the most appropriate one among the different possible compositions. One possible solution is to use quality of service (QoS) to evaluate, compare and select the most appropriate composition(s). The QoS is defined as a combination of the different attributes of the Web services such as availability, response time, throughput, etc. The QoS is an important element of Web services and other modern technologies. Currently, most of works use successive evaluation of different, non functional, aspects in order to attribute a general "level of quality" to different composite Web services and to select the "best" one from these services. In these works, the evaluation of composite Web services is based either on a single evaluation criterion or, at best, on a weighted sum of several quantitative evaluation criteria. Both evaluation schemas are not appropriate in practice since: (i) a single criterion does not permit to encompass all the facets of the problem, (ii) weighted sum-like aggregation rules may lead to the compensation problem since worst evaluations can be compensated by higher evaluations, and (iii) several QoS evaluation criteria are naturally qualitative ones but weighted sum-like aggregation rules cannot deal with this type of evaluation criteria.

The goal of this research is to propose a general framework to composite Web services selection based on multicriteria evaluation. The proposed framework extends the Web services architecture by adding, in the registry, a new Multicriteria Evaluation Component (MEC) devoted to multicriteria evaluation. This additional component takes as input a set of composite Web services and a set of evaluation criteria. The output is a set of recommended composite Web services. The paper also proposes a solution to generate the different potential compositions which will be the main input for the MEC. Further, the paper shows how composite Web services can be evaluated.

The paper is organized as follows. Section 2 presents some related work. Section 3 details the architecture of the proposed framework. Section 4 presents the implementation of the proposed architecture. Section 5 presents the Multicriteria Evaluation Component. Section 6 shows how the set of potential composite Web services is constructed. Section 7 discusses the problem of composite Web service evaluation. Section 8 concludes the paper.

2 Related work

As underlined in the introduction, to choose among the different possible compositions, most of previous works use either a single QoS evaluation criterion or a weighted-sum of serval quantitative QoS evaluation criteria. The following are some examples. The author in [Men04] considers two evaluation criteria (time and cost) and assigns to each one a weight between 0 and 1. The single combined score is computed as a weighted average of the scores of all attributes. The best composition of Web services can then be decided on the basis of the optimum combined score. One important limitation of this proposal is the compensation problem mentioned earlier.

In [GSC+99], the service definition models the concept of "placeholder activity" to cater for dynamic composition of Web services. A placeholder activity is an abstract activity replaced on the fly with an effective activity. The author in [CIJ+00] deals with dynamic service selection based on user requirement expressed in terms of a query language. In [Kli00], the author considers the problem of dynamically selecting several alternative tasks within workflow using QoS evaluation. In [BDS+02], the service selection is performed locally based on a selection policy involving the parameters of the request, the characteristic of the services, the history of past executions and the status of the ongoing executions. One important shortcoming of [GSC+99][CIJ+00][Kli00][BDS+02] is the use of local selection strategy. In other terms, services are considered as independent. Within this strategy, there is no guarantee that the selected Web service is the best one.

To avoid the problem of sequential selection, Zeng et *al.* [ZBD+03] propose the use of linear programming techniques to compute the "optimal" execution plans for composite Web service. However, the multi-attribute decision making approach used by the authors has the same limitation as weighted-sum aggregation rules, i.e., the compensation problem.

Maximilien and Singh [MS04] propose an ontology-based framework for dynamic Web service selection. However, they consider only a single criterion, which is not enough to take into account all the facets of the problem.

Menascé and Dubey [MD07] extends the work of Menascé et al. [MRG07] on QoS brokering for service-oriented architectures (SOA) by designing, implementing, and experimentally evaluating a service selection QoS broker that maximizes a utility function for service consumers. These functions allow stakeholders to ascribe a value to the usefulness of a system as a function of several QoS criteria such as response time, throughput, and availability. This framework is very demanding in terms of preference information from the consumers. Indeed, consumer should provide to a QoS broker their utility functions and their cost constraints on the requested services. However, the most limitation of this work is the use of weighted-sum like optimization criterion, leading to compensation problem as mentioned earlier. One important finding of this paper is the use, by the QoS broker, of analytic queuing models to predict the QoS values of the various services that could be selected under varying workload conditions.

More recently, [MZ08] use genetic algorithm for Web service selection with global QoS constraints. The authors integrate two policies (an enhanced initial policy and an evolution policy), which permits to overcome several shortcomings of genetic algorithm. The simulation on Web service selection shown an improved convergence and stability of genetic algorithm.

3 Extended Web service architecture

The Web service architecture is defined by 3WC in order to determinate a common set of concepts and relationships that allow different implementations working together [CNO02]. The Web service architecture consists of three entities, the service provider, the service registry and the service consumer. The service provider creates or simply offers the Web service. The service provider needs to describe the Web service in a standard format, which is often XML, and publish it in a central service registry. The service registry contains additional information about the service provider, such as address and contact of the providing company, and technical details about the service. The service consumer retrieves the information from the registry and uses the service description obtained to bind to and invoke the Web service.

The proposed framework, in this paper, extends the Web services architecture by adding, in the registry, a new Multicriteria Evaluation Component (MEC) devoted to multicriteria evaluation. The general schema of the extended architecture is given in Figure 1. According to the requirement of the consumer, the registry opts either for conventional evaluation or for multicriteria evaluation. By default, the registry uses conventional evaluation; multicriteria evaluation is used only if the consumer explicitly specifies this to the registry manager. This ensures the flexibility of the proposed architecture.

However, the application of a multicriteria method needs the definition of a set of preference parameters. The definition of these parameters needs an important cognitive effort from the consumer. To reduce this effort, MEC uses specific Web service called W-IRIS which is a Web version of IRIS (Interactive Robustness analysis and Parameters Inference for multicriteria Sorting Problems) [DM03] system permitting to infer the different preference parameters.

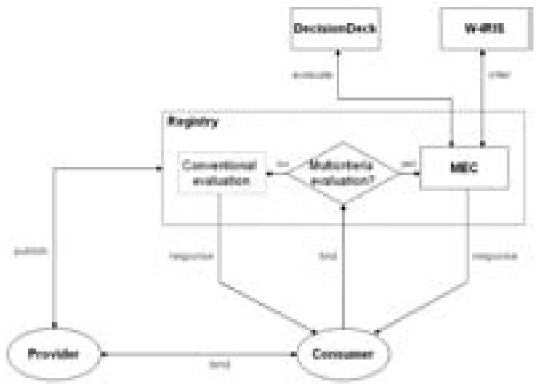

Figure 1: Extended architecture of Web services

As we can see in Figure 1, the three basic operations of the Web service architecture denoted by publish, bind and find still exist. Two additional operations, denoted by keywords infer and evaluate are included in the extended architecture. The first permits to handle data exchange between MEC and W-IRIS. The latter permits to handle data exchange between MEC and DecisionDeck platform.

To achieve the interaction among the entities of the extended Web service model, we need to extend some SOAP protocoles and add new ones. More specifically, we need to extend protocols of consumer request to registry and registry response to consumer; and add the ones relative to MEC request to W-IRIS and W-IRIS response to MEC. A detailed description of the proposed architecture is given in Figure 2.

W-IRIS permits to infer the different preference parameters needed to apply multicriteria evaluation using ELECTRE TRI method. The inference procedure included in W-IRIS needs the resolution of different mathematical programs. For this purpose, W-IRIS includes the solver GLPK, which is an open-source and free package (see [Mak05]).

The current version of MEC supports the advanced multicriteria method ELECTRE TRI (see [FGE05]) and several elementary methods (weighted sum, conjunctive and disjunctive rules and the majority rule). Additional methods will be included in the future via the DecisionDeck platform. The DecisionDeck platform is issued from D2-Decision Deck project that has started in 2003 under the name EVAL, an acronym which refers to an ongoing research project funded by the Government of the Walloon region (Belgium). The aim is to develop a Web-based platform to assist decision makers in evaluating alternatives in a multicriteria and multi-experts context.

In the following, we present the jUDDI extensions and its implementation. More precisely, we detail the required extension/addition to support data exchange between the different entities of the proposed architecture.

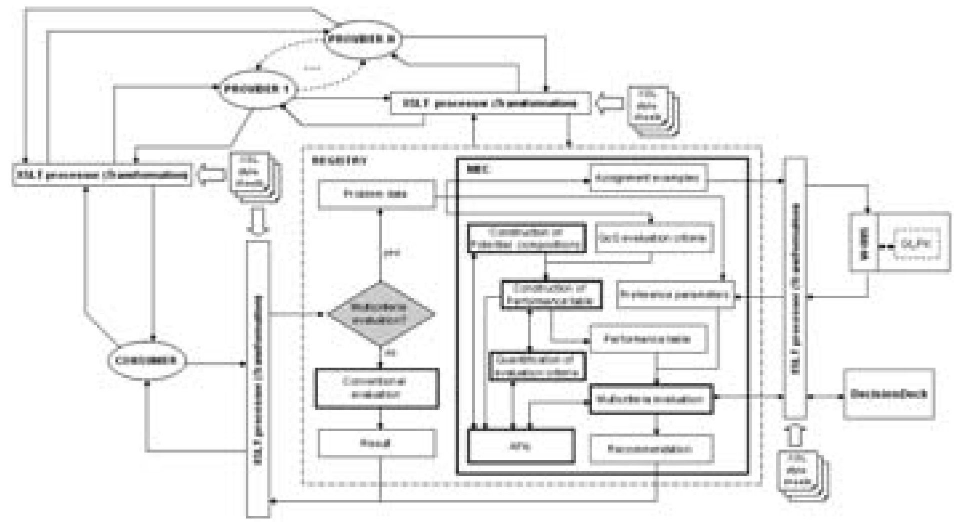

Figure 2: Dynamics of the system

4 jUDDI extension and implementation

jUDDI information model is composed of data structure instances expressed in XML schema. They are stored in jUDDI registries. A service is discovered by sending requests based on service information. The four core data elements within the jUDDI data model are described bellow (more information can be found in http://juddi.og): i) businessEntity: contains informations business, such as name and contact (each entity may provide various businessEntity); ii) businessService: contains informations about published services; iii) bindingTemplate: represents a service implementation and provides the information needed to bind with the service; and iv) tModel: is used to establish the existence of a variety of concepts and to point to their technical definitions.

In addition to the existence entities, we defined the following elements: i) qosInscription: contains customers who wish to take into account the QoS in their search of services in the extended registry; ii) qosParameters: contains the different parameters, for each customer registered to this option, needed to use multicriteria methods. Note that these parameters can be provided directly by the user or deduced using W-IRIS service (see Sect. 6); iii) qosDescription: contains the QoS values for each service provider. The provider requests service publication and providers the QoS values. These last are checked and validated by the registrymanager. Note that QoS values can be update by the registry manager, and if a value is not provided, thus it is valued at worst. The qosDescription table refers to the bindingTemplate table that stores Web services instances. It also refers to the tModel.

The registry is implemented using Apache jUDDI Version 0.4rc4 which is an open source UDDI implementation compliant with Version 2.0 specification. MySQL Version 5.0.16 was used to implement the jUDDI databases. UDDI4J (version 2.0.4) is an open source Java class library that provides an APIs (Application Programming Interfaces) to interact with a jUDDI. They are grouped in three APIs categories: i) Iniquity APIs set, ii) Publication APIs set and iii) Security APIs set. The extended registry includes extensions to the UDDI4J Inquiry and Publication APIs set in order to manipulate the QoS related data. The extended registry is done thought registry manager, who implements the QoS management operations (see Sect. 3). Experiments results, by simulation, are effectuated and show the compatibility withe the basic UDDI and both types of UDDI registries and can coexist in the same environment.

The W-IRIS is a special kind of Web service used by MEC to infer the preference parameters to use with ELECTRE TRI method. This method is used by MEC to assign composite Web services into different categories. It applies when "type of result" in the SOAP message sent by the consumer to registry is "sorting" (see Figure 3). The XML schema of the "infer" SOAP message sent by the MEC to W-IRIS and the same information are included in the "sorting_data" element (see Figure 3).

In the most general case, the inputs of W-IRIS are: (i) the number of categories, (ii) a set of profile limits, and (iii) a set of assignment examples. All of these data are extracted from the SOAP message sent by the consumer to registry detailed in the previous subsection (see Figure 3). As underlined earlier, the number of categories is an optional parameter and when it is omitted, three categories are automatically used.

In the case where the profile limits are not provided by the consumer, they will be automatically constructed by MEC. To this purpose, the measurement scale of each QoS evaluation criterion included in the "find" SOAP message sent by the consumer to the registry is subdivided into three equal intervals. Then, profile limits are defined by joining the limits of these intervals on the different evaluation criteria.

```
<xsd:schema xmlns:xsd="http://www.w3.org/2000/10/XMLSchema">
<xsd:complexType element name="infer">
 <xsd:sequence>
  <xsd:element name="sorting_data">
 </xsd:sequence>
</xsd:complexType>
<xsd:complexType name="sorting_data">
   <xsd:element name="categories_number" type="xsd:positiveInteger">
   <xsd:element name="profiles">
   <xsd:element name="assignment_examples">
</xsd:complexType>
    ...
```

Figure 3: XML schema of MEC request to W-IRIS

The set of assignment examples are defined as follows. First, MEC generates a set of fictive compositions. Each fictive composition k_f is associated with a vector of m elements $(g_1(k_f), g_2(k_f), \cdots, g_m(k_f))$, where m is the number of QoS evaluation criteria. Evaluations $g_j(k_f)$ $(j = 1, \cdots, m)$ are defined such that k_f may be assigned to two succussive categories. For better explanation, consider two categories C_i and C_j and let b_h be the profile limit between C_i and C_j with evaluation vector $(g_1(b_h), g_2(b_h), \cdots, g_m(b_h))$. Then, a fictive composition k_f is defined such that its performances on a subset of QoS evaluation permits to assign it to C_i and the rest permits to assign it to C_j.

XML schema of W-IRIS "inference_ouptut" SOAP message to MEC is given in Figures 3. It is a collection of preference parameters and the corresponding values. These parameters will be used by MEC to apply ELECTRE TRI.

```
<xsd:schema xmlns:xsd="http://www.w3.org/2000/10/XMLSchema">
<xsd:complexType element name="inference_output">
 <xsd:sequence>
  <xsd:group ref="preference_parametersGroup">
 </xsd:sequence>
</xsd:complexType>
<xsd:group name="preference_parametersGroup">
 <xsd:sequence>
   <xsd:element name="preference_parameter" type="preference_parameterType" minOccurs="1">
 <xsd:sequence>
</xsd:group>
<xsd:complexType name="preference_parameterType">
 <xsd:sequence>
  <xsd:element name="name"  type="token" #REQUIRED>
  <xsd:element name="value"  type="anyType"  #REQUIRED>
 </xsd:sequence>
</xsd:complexType>
```

Figure 4: XML schema of W-IRIS response to MEC

5 Multicriteria evaluation component

The general schema of multicriteria evaluation component (MEC) is depicted in Figure 1. Basically, it takes as input a set of composite Web services and a set of QoS evaluation criteria and generates a set of recommended compositions. The final choice should be performed by the consumer, based on the MEC recommendation. In the rest of the paper, $K = \{k_1, k_2, \cdots, k_n\}$ denotes a set of n potential composite Web services and $I = \{1, 2, \cdots, n\}$ denotes the indices of these services. The solution proposed to construct set K will be detailed in Sect. 6.

The set of QoS evaluation criteria to be used is extracted from the "qosDescription" data of the extended registry (see Sect. 4). The set of evaluation criteria will be denoted by $F = \{g_1, g_2, ..., g_m\}$ in the rest of the paper. Theoretically, there is no limit to the number of criteria. We observe, however, that a large set increases the cognitive effort required from the consumer and a few ones do not permit to encompass all the facets of the selection problem.

The quantification of evaluation criteria permits to transform qualitative evaluation criteria into quantitative ones by assigning values to the qualitative data. This is useful for mostly of multicriteria methods based on weighted-sum like aggregation decision rules. The most used quantification method is the scaling one. The quantification process consists in the definition of a measurement scale as the one mentioned earlier and then to associate to each level of the scale a numerical value.

Once potential composite Web services are constructed and evaluation criteria are identified, the next step consists in the evaluation of all these composite Web services against all the evaluation criteria in F. The evaluation of a composite Web Service $k_i \in K$ in respect to criterion $g_j \in F$ is denoted $g_j(k_i)$. The matrix $[g_j(k_i)]$, $\forall i \in I$, $\forall j \in F$ is called the performance table. The computing of $g_j(k_i)$, $\forall i \in I, \forall j \in F$, will be dealt with in Sect. 7.

Most of multicriteria methods require the definition of a set of preference parameters. Two cases hold here: either the preference parameters are provided explicitly by the consumer and extracted from the "find" SOAP message to the registry; or inferred by W-IRIS based on the assignment examples equally extracted from the "find" SOAP message sent by the consumer.

The input for multicriteria evaluation step are the performance table and the preference parameters. The objective of multicriteria evaluation is to evaluate and compare the different compositions in K.

As signaled above the advanced multicriteria method ELECTRE TRI and four elementary methods (weighted sum, conjunctive and disjunctive rules, and the majority rule) are incorporated in the framework.

As underlined above, three types of recommendations are possible within the proposed framework. Based on the specifications of the consumer, one of the following results is provided to it: i) one or a restricted set of composite Web services; ii) a ranging of composite Web services from best to worst with eventually equal positions and iii) a classification of composite Web services into different pre-defined categories.

These three types of result correspond in fact to the three ways usually used to formalize multicriteria problems as identified by [Roy95]: *choice*, *ranking* and *sorting*.

6 Constructing potential composite Web services

Definition 1 *A **Web service** S_i is a tuple (F_i, Q_i, H_i), where: i) F_i is a description of the service's functionality; ii) Q_i is a specification of its QoS evaluation criteria and iii) H_i is its cost specification.*

We assume that each Web service S_i has a unique functionality F_i. In turn, the same functionality may be provided by different providers. Let P_i be the collection of providers supporting functionality F_i of Web service S_i: $P_i = \{s_i^1, s_i^2, \cdots, s_i^{n_i}\}$ where n_i is the number of providers in P_i. A composite Web service is defined as follows.

Definition 2 *Let $S_1, S_2, \cdots, S_n$ be a set of n individual Web services such that $S_i = (F_i, Q_i, H_i)$ $(i = 1, \cdots, n)$. Let P_i be the collection of Web services supporting functionality F_i. Let $G = (X, V)$ be the composition graph associated with $S_1, S_2, \cdots, S_n$. A **composite Web service** k is an instance $\{s_1, s_2, \cdots, s_n\}$ of G defined such that $s_1 \in P_1$, $s_2 \in P_2$, $\cdots$, $s_n \in P_n$.*

To construct the set of potential compositions, we have incorporated two algorithms in the

MEC. The first one, called `CompositionGraph` and is not given here which permits the construction of the composition graph.

The second algorithm, given hereafter, is `CompositionsConstruction` that generates the potential compostions. This algorithm proceeds as follows. First a tree T is constructed using `Construct_Tree`. The inputs for this procedure is the set of nodes X and the set of providers for each node in X: $P = \{P_1, P_2, \cdots, P_n\}$. The tree T is constructed as follows. The nodes of the ith level are the providers in P_i. For each node in level i, we associate the providers in set P_{i+1} as sons. The same reasoning is used for $i = 1$ to $n-1$. The nodes of the $n-1$th level is associated with the providers in P_n. Finally, a root r is added to T as the parent of nodes in the first level (representing the providers in P_1). Then, the set of nodes for each composition is obtained as an elementary path in T.

```
Algorithm CompositionsConstruction

INPUT: G = (X, V): composition graph
       P = {P_1, P_2, ..., P_n}: providers
OUTPUT: K: potential compositions

T ← Construct_Tree(X, P)
t ← 1

WHILE t <= ∏_{i=1}^{n} |P_i|
    X_t ← ElementaryPath(T)
    //X_t = {s_1, s_2, ..., s_n}
    FOR each (S_h, S_k) ∈ V
            V_t ← (s_h, s_k)
    END_FOR
k_t ← G_t = (X_t, V_t)
K ← K ∪ k_t
t ← t + 1
END_WHILE
```

The complexity of algorithm considered algorithm is $O(r_1 \times (r_2 + r_3))$ where $r_1 = |V|$ is the cardinality of V, $r_2 = \prod_{i=1}^{n} |P_i|$ is the number of compositions and r_3 is the complexity of `ElementaryPath`.

7 Evaluation of compositions

As defined earlier, a potential composition is an instance of the composition graph $G = (X, V)$. Each composition can be seen as collection of individual Web services. The evaluation provided by the UDDI registry are relative to these individual Web services. However, to evaluate and compare the different potential compositions, it is required to define a set of rules to combine the partial evaluations (i.e. in respect to individual Web services) to obtain partial evaluations that apply to the whole composition.

To compute the partial evaluations $g_j(k_i)$ ($j = 1, \cdots, m$) of the different compositions k_i ($i = 1, \cdots, n$), we need to define a set of m aggregation operators $\Phi_1, \Phi_2, \cdots, \Phi_m$, one for each evaluation criterion. The partial evaluation of a composition k_i on criterion g_j, $g_j(k_i)$, is computed as follows. It consists in applying a bottom-top scan on graph $G_i = (X_i, V_i)$ and to apply the aggregation operator Φ_j on each node. Algorithm

`PartialEvaluation` below implements this idea. It runs on $O(r^2)$ where $r = |X|$ is the number of nodes in the composition graph. The valuation, in respect to criterion g_j, of a node $x \in X_i$, denoted $v_j(x)$, is computed as follows: $v_j(x) = \Phi_j[g_j(x), \Omega(\Gamma^+(x))]$.

Recall that $\Gamma^+(x)$ is the set of successors of node x. The operator Ω involves nodes on the same level and may be any aggregation operator such as `sum`, `product`, `max`, `min`, `average`, etc. The operator Φ_j implies nodes on different levels and vary according to the BPEL constructors associated with node x. It may be the `sum`, `product`, `max`, `min`, or `average`.

```
Algorithm PartialEvaluation

INPUT: k_i = G_i(X_i, V_i): composition
       Φ_j: aggregation operators
OUTPUT: g_j(k_i): partial evaluation of k_i on g_j

L_r ← {s ∈ X_i : Γ+(s) = ∅}
Z ← ∅

WHILE Z ≠ X_i
    FOR each x ∈ L_r
        v_j(x) ← Φ_j[g_j(x), Ω(Γ+(x))]
        Z ← Z ⋃{x}
    END_FOR
    L_r ← {s ∈ X_i : v_j(w) is computed ∀w ∈ Γ+(s)}
END_WHILE

g_j(k_i) ← v_j(s) where s is the root of G_i
```

In the following, we provide the proposed formula for computing $v_j(x)$ ($j = 1, \cdots, 4$) for response time, availability, cost and security evaluation criteria, denoted g_1, g_2, g_3 and g_4, respectively. Evaluation criteria g_1 and g_3 are to be minimized while criteria g_2 and g_4 are to be maximized. The three first criteria are cardinal. The latter is an ordinal one.

First, we mention that the following formula apply for non-leaf nodes, i.e., $x \in X_i$ such that $\Gamma^+(x) \neq \emptyset$. For leaf nodes, i.e. $x \in X_i$ such that $\Gamma^+(x) = \emptyset$, the partial evaluation on a criterion g_j is simply $v_j(x) = g_j(x)$.

Response time (g_1) The response time of a non-leaf node x is computed as follows: $v_1(x) = g_1(x) + \max\{v_1(y) : y \in \Gamma^+(x)\}$ *or* $v_1(x) = g_1(x) \quad + \sum_{y \in \Gamma^+(x)} \pi(x,y)\, v_1(y)$

The first part of $v_1(x)$ applies for the <`flow`> or the sequential BPEL constructors. The second part applies when the constructor <`switch`> is used.

Availability (g_2) For the availability, two formulae may be applied for respectively the <`flow`> or the sequential constructors and the <`switch`> constructor:
$v_2(x) = g_2(x) \prod_{y \in \Gamma^+(x)} v_2(y)$ *or* $v_2(x) = g_2(x) \sum_{y \in \Gamma^+(x)} \pi_(x,y)\, v_2(y)$

Cost (g_3) For cost criterion, two formula may be used for respectively the <`flow`> or the sequential constructors and the <`switch`> constructor:
$v_3(x) = g_3(x) + \sum_{y \in \Gamma^+(x)} v_3(y)$ *or* $v_3(x) = g_3(x) + \sum_{y \in \Gamma^+(x)} \pi(x,y)\, v_3(y)$

Security (g_4) Finally, for security criterion, we have:
$v_4(x) = \min\{g_4(x), \min_{y\in\Gamma^+(x)}\{v_4(y)\}\}$

8 Conclusion

We have proposed a framework for composite Web services selection based on multicriteria evaluation. The framework extends the Web services architecture by adding a new Multicriteria Evaluation Component (MEC) devoted to multicriteria evaluation. This additional component takes as input a set of composite Web services and a set of evaluation criteria. The output is a set of recommended composite Web services. We also proposed solutions to construct and evaluate the different potential compositions. To show the feasibility of our proposal, we have developed a prototype based on the jUDDI registry.

There are several directions for future research. A first point to investigate is related to the extension of the framework to support dynamic composition. The basic change concerns essentially the construction of the potential compositions and their evaluations.

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The Subprocess Spectrum

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Abstract: Using hierarchical structurings in process design is a frequent process modeling technique. Subprocesses are a common way to enable hierarchical structuring. Current approaches have a tight view on the syntactical restrictions of subprocesses and do not investigate different autonomy properties in detail. This paper fills this gap and broadens the current subprocess definition to a spectrum of possibilities of subprocess notations. Thereby, three classifications are introduced: subprocess autonomy, interaction between parent process and subprocess, and execution of subprocesses.

1 Introduction

"Sub" and "process" together form the term "subprocesses". "Sub" implies that something is below something else and that something is on the bottom, which is closely related to hierarchies. For instance, hierarchies are introduced within organizations in order to form an ordering between a set of entities. Hierarchies are relations of power, i. e., the entity superordinate can control the subordinate entity concerning certain properties. For example, within a company a manager has managerial authority over his staff. In the context of processes, subprocesses also introduce a hierarchy between a set of processes. The aim of this work is to present the properties of the relation between two processes, where one process is below another process and hence is called "*sub*process".

Subprocesses are introduced in [LR00] as a modeling construct used for modeling reusable business processes. Subprocesses are required to have a single logical entry and a single logical exit. They are not allowed to communicate with the calling process inbetween. Subprocesses also have a strong lifecycle dependency on the caller. This coupling effectively means that the subprocess has to give up his lifecycle autonomy: the subprocess has to be terminated if the calling activity is terminated. If the calling activity is compensated, the entire subprocess has to be compensated.

In this paper, we call those subprocesses "traditional subprocesses" and use the term "subprocesses" for extended traditional subprocesses, which have more defined properties than traditional subprocesses. We present in Sect. 2 taxonomies of these properties to enable a classification of subprocesses. The taxonomies differentiate autonomy properties, the interaction between parent process and subprocess, and the execution of subprocesses. Using the taxonomies, we provide a new subprocesses definition and a comparison to choreographies in Sect. 3. Related work in the field of subprocesses is presented in Sect. 4. Finally, Sect. 5 provides a conclusion and provides and outlook on future work.

We focus on business processes executed fully on a workflow engine (called "workflow" in [LR00]). Internal activities may be executed by humans, which is usually implemented using human tasks. The coordination between actions of the workflow engine and actions of humans is handled by the task manager. An example of such an action is termination of an activity. The description of these issues is out of scope of this paper.

2 Taxonomies

This section provides three taxonomies for subprocesses: autonomy (Sect. 2.1), interaction (Sect. 2.2) and execution (Sect. 2.3). These taxonomies can be used to classify subprocesses and provide a definition for extended traditional subprocesses as presented in Sect. 3.

2.1 Autonomy

Autonomy properties describing the autonomy of the subprocess can be distinguished into five different subclasses (Fig. 1), each regarding a different aspect of autonomy and its renunciation. In the following, we describe each autonomy class and assign existing approaches to a class. As future research may find new approaches, the presented taxonomy is necessarily not complete.

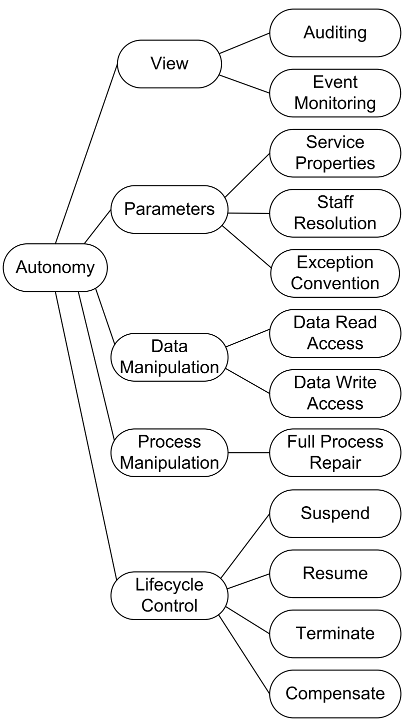


Figure 1: Autonomy Taxonomy

View Providing different views is key for business process execution and business process compliance checking [SLS10]. For instance, a part of a business process may be outsourced [KL06]. Then, the outsourcing company may still have the obligation to show that the outsourced parts follow a compliance rule. Another example are external services that may only be bound to a business process if they offer to track its audit trails from the caller's side. Hence, a service has to state whether it offers access to its *audit* trails and how long these audit trails are kept [LR00]. External *event monitoring* may be needed if cross-organizational process metrics have to be calculated [WKK+10].

Parameters Available parametrization possibilities of subprocesses include changing of service properties, parametrization of staff resolution and promising the raise of certain exceptions. Changing of *service properties* is described in [KLN$^+$06]. There, strategies are described to change the WSDL port type and WSDL operation of a process at both, deployment and runtime. For example, these parameters may be set at the call of the subprocess to set specific services the subprocess has to use. In the case of *staff resolution*, the parent process sets staff resolution parameters [LR00] such as the organizational data base to be used or the group of people to select from. A subprocess may fault because of an erroneous situation. In this case, it does not reply with a result message, but with a fault message. Using an *exception convention*, the subprocess assures that it will rise certain exceptions in the respective situations. This is used to ensure that (i) all known exceptions are raised and (ii) the raised exceptions can be handled by the parent process.

Data Manipulation A subprocess may read variables and correlation sets of the caller and the caller may read variables and correlation sets of the subprocess. This enables parameter passing by reference in contrast to value passing in traditional subprocesses (*data read access*). Data manipulation also includes *data write access*, where data is shared and may be updated by the other party. Note that "data" excludes "parameters": "data" denotes data where the process has direct access to during execution, whereas "parameters" denote data used by the workflow engine to execute the process.

Process Manipulation A process may be adapted to fulfill new requirements or to enable *full process repair* in erroneous situations. In case values of variables have to be changed to repair the process, data write access has also be enabled. An overview on process manipulation and adaption is given in [RRMD09].

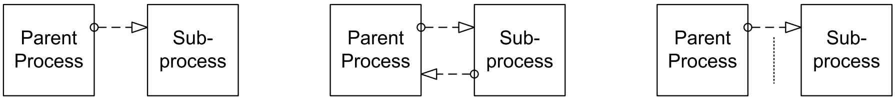
Lifecycle Control In traditional subprocesses there exist lifecycle dependencies between parent process and subprocess. Lifecycle dependency consists of suspending and resuming a subprocess, termination of the subprocess and compensation of a completed subprocess.

The concrete implementation of these properties is not presented in this paper. The autonomy properties may be handled by software or by organizational measures. In the case of manual processes the property data sharing may manifest itself by a company regulation that how folders of a manual parent process can be accessed. For instance, a written form to request the folder may be used.

2.2 Interaction between Parent Process and Subprocess

This section investigates all possible interaction patterns and the possible internal structures of subprocesses and parent process. The outcome of this investigation can be used in future work to define collaboration and coordination protocols between parent and subprocess.

Message Exchange Patterns (MEPs) denote a set of messages and the order in which these messages are sent or expected to be received [NvLL08], also called "interaction". Autonomy properties may influence the MEPs. For instance, a termination of a subprocess also leads to a stop of the MEP as no further messages are exchanged. There are two solutions to this issue: (i) the MEPs model the "happy path" through the process. The exceptional behavior has to be derived from the process. (ii) All possible message exchanges have to be enumerated. In this case, operating guidelines may be used [LMW07]. In this paper, we



(a) send only (b) send and receive (c) send and arbitrary subsequent interactions

Figure 2: Possible Message Exchanges

follow the first approach, as it follows the widely used approach to separate the normal flow from the exception flow.

2.2.1 Parent process / Subprocess Message Exchange Patterns

The process interaction between a parent and a subprocess is restricted such that the subprocess always gets started by receiving a message sent by the parent process. Figure 2 presents the three different kinds how the interaction may continue: send only, send and receive, send, arbitrary interactions and optionally a final reply message.

Figure 2a depicts the *send only* pattern. A subprocess gets spawned by the parent process and no further synchronization between the two processes is taking place. This interaction pattern is also called “kick off and forget”, “connected discrete” and “chained services model” [LR00, Hol95]. The pattern used in the case of traditional subprocesses is shown in Fig. 2b: the subprocess first receives a message and finally replies with a message. This pattern is also called “hierarchical” [LR00, Hol95] or “functional de-composition” [HZ07]. Figure 2c presents the general interaction with a subprocess: the parent process sends a message to the subprocess. Then, they communicate arbitrarily with each other.

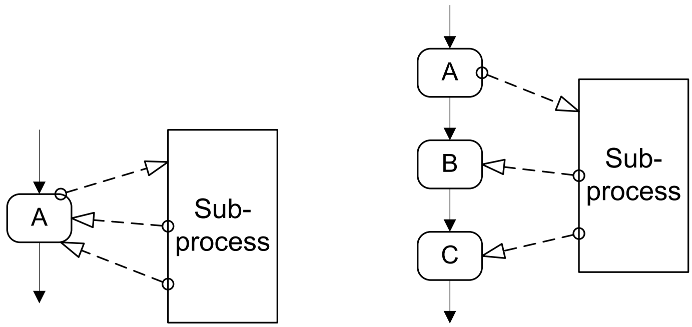
In case there is no final reply message, a coordination protocol has to provide the parent process the information that the subprocess is finished. This enables the calling process to drive the lifecycle autonomy implementation: in case a subprocess is running, it may only be terminated and not be compensated. In case a subprocesses is completed, it may only be compensated and not be terminated.

2.2.2 Parent Process MEP Implementations

The interaction with the subprocess can be implemented in the parent process in two ways: It is possible to model the interaction with the subprocess using a single activity implementing the MEP (Fig. 3a) or using multiple activities to implement the MEP (Fig. 3b). There can be also variants between these two possibilities: Parts of a MEP can be realized using single activities and the remaining parts using activities implementing multiple message exchanges.

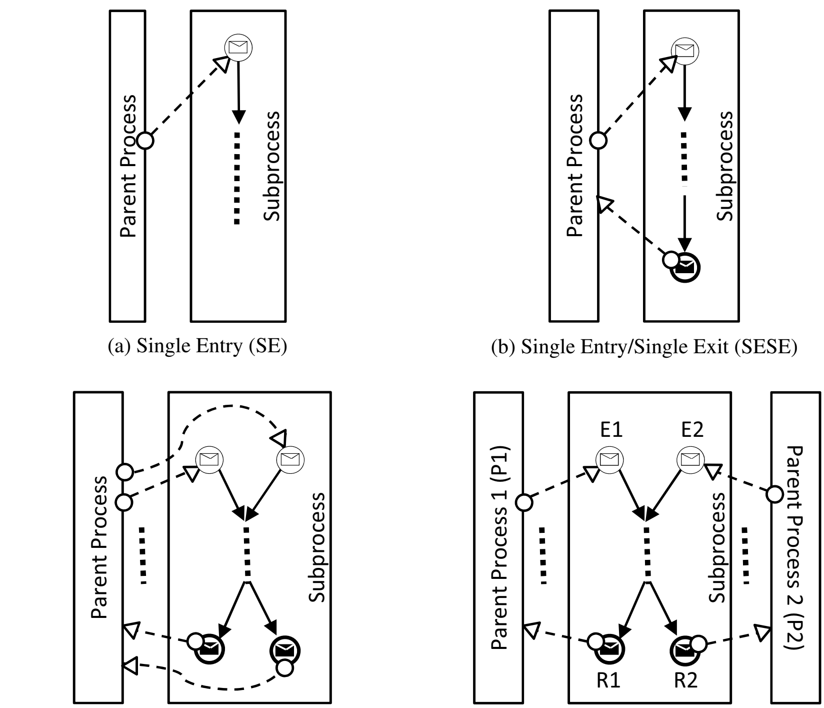
2.2.3 Subprocess Structures

The structure of a traditional subprocess is Single Entry/Single Exit (SESE). Subprocesses, however, may be structured differently as presented in Fig. 4. The simplest structure of



(a) single activity (b) multiple activities

Figure 3: Parent Process Structures to implement MEPs



(a) Single Entry (SE)

(b) Single Entry/Single Exit (SESE)

(c) Multiple Entries/Multiple Exists (MEME), one partner

(d) Multiple Entries/Multiple Exists (MEME), multiple partners

Figure 4: Subprocess Structures: Possible Entry and Exit Patterns

a subprocess contains a single entry and no exit (Fig. 4a). The traditional subprocess interaction pattern SESE is presented in Fig. 4b. A subprocess may also have multiple entries and multiple exists (MEME) as presented in Fig. 4c.

Multiple entries may be mutual exclusive. This transforms the entry to a logical single entry: the parent process may only use one of the multiple entries. After using the entry, the subprocess is instantiated and does not wait for the second message. Similarly, multiple exists may be mutually exclusive which transform them to a single logical exit. In case a subprocess has a single logical entry and a single logical exist, it falls into the category "SESE", since the caller cannot distinguish between the exits.

In case a subprocess has multiple entries, these entries may be used by different calling processes as shown in Fig. 4d. Here, process P1 uses entry E1 and exit R1, process P2 uses entry E2 and exit R2. Activities on the path w1 from P1 to R1 and on the path w2 from P2 to E2 fall into three categories: (i) only on the path w1, (ii) only on the path w2 and (iii) both on the path w1 and w2. Depending on the autonomy, the whole subprocess has to fulfill the autonomy requirements of the calling process or the activities on the execution path of the calling process. This might have influence on the response time of the process to other partners. The concrete relationship of autonomy and service level agreements [UMLS08] has not been investigated yet. A concrete classification and investigation of the interplay between different autonomy degrees is out of scope of this paper.

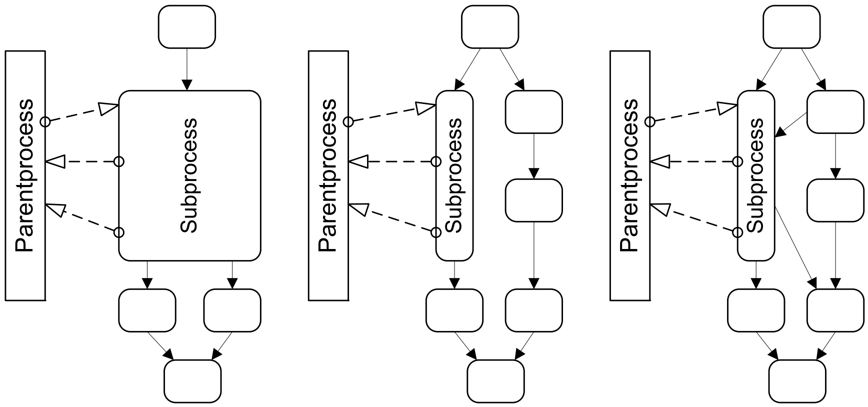
2.2.4 Subprocess Embedding

The subprocess may be a part of a larger process as illustrated in Fig. 5. Figure 5a presents the case where the subprocess is nested in a process without parallel activities. In this case, execution of the subprocess is not influenced by any other activity in the process, as no parallel execution happens outside. Figure 5b presents a case with activities executing in parallel to the subprocess. On the one hand, the subprocess may be aborted due to a fault in parallel activities. Suppose an activity A runs in parallel to a subprocess S. Assume A and S nested in the same parent activity P. Then, a fault in A is propagated to P, which causes S to terminate [CKLW03, BPE07]. This is behavior is independent of existing control links between A and S. On the other hand, a fault in the subprocess may in turn abort parallel activities. Figure 5c presents the case where control links cross the boundary of the subprocess. Thus, the autonomy of the subprocess also influences the execution behavior of the other activities. For instance, if the subprocess is suspended and subsequent control links reach from the subprocess to activities not being in the subprocess, the navigation there has to wait for the subprocess to be resumed.

2.2.5 Recursive Subprocess Calls

Figure 6 illustrates a case, where a subprocess calls another process. This process is then a subprocess to the calling subprocess and a "grand-subprocess" to the parent process. In this situation, the autonomy degree of the sub-subprocess must not be higher than the autonomy degree of the subprocess. For instance, if the subprocess has no lifecycle autonomy it must be the case that the sub-subprocess must have no lifecycle autonomy, too. More subordination for the sub-subprocess is possible, but lifecycle subordination is mandatory.

The subprocess is typically not an instance of the same process model as the calling process.



(a) subprocess nested in a process

(b) subprocess with a parallel process branch

(c) subprocess with cross-boundary links from parallel process branch

Figure 5: Subprocess Structures: Embedded Subprocesses

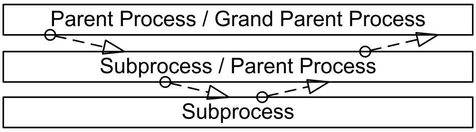


Figure 6: Recursive Subprocess Calls

The word "recursive" refers to the metamodel level: a process of the type "subprocess" calls another process of the type "subprocess".

2.3 Execution of Subprocesses

Subprocesses can be executed on the same workflow management system as the caller or on a different system. The first kind of subprocesses is called *local subprocess*, whereas the second kind is called *remote subprocess* [LR00].

3 Definition of Subprocess

The preceding section provided three classifications. Using these classification, traditional subprocesses and extended traditional subprocesses can be compared as presented in Fig. 7. There, the different execution possibilities of subprocesses have been dropped as traditional subprocesses as well as subprocesses allow both a local and remote execution. The Y-axis presents different autonomy degrees (cf. Sect. 2.1). Here, all different combinations of the autonomy properties are sketched. A traditional subprocess is always fully lifecycle dependent, whereas subprocesses allow a flexible choice of autonomy properties. The

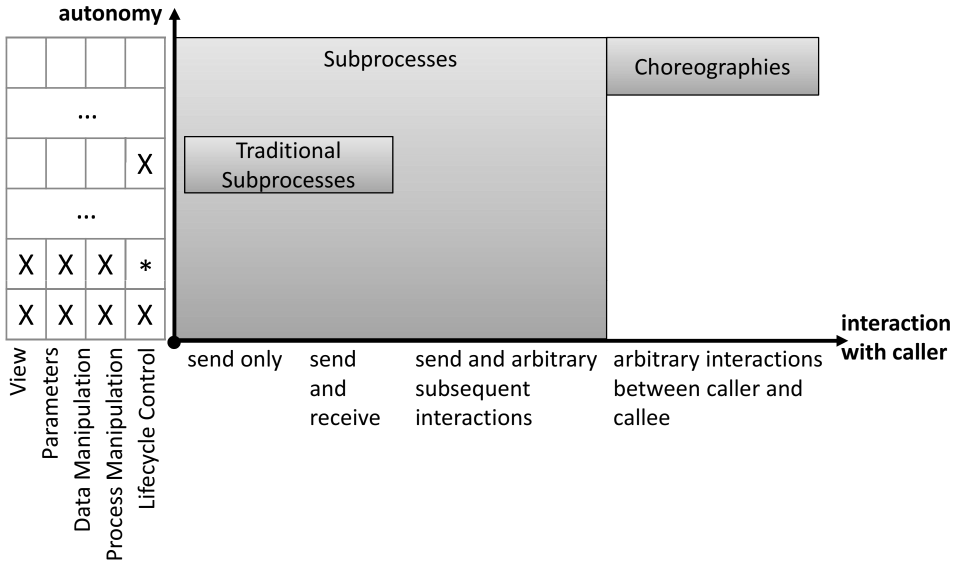


Figure 7: Subprocess Spectrum Overview. "X" denotes all autonomy properties of the respective class. "*" denotes the subset "suspend, resume and terminte" of the class "lifecycle control". "···" denotes that there are more combinations of autonomy properties, which are not explicitly shown in the table.

X-axis presents different interactions (cf. Sect. 2.2). In the case of subprocesses, a parent process always triggers interaction with a subprocess and an interaction is never started by a subprocess. In case arbitrary interactions between the parties are allowed, we are in the field of choreographies. A choreography describes the interaction between multiple processes, focusing on the interactions only or modeling internal behavior, too [DKLW09]. Current choreography languages do not offer to model autonomy degrees. Thus, choreographies are placed in the top of the diagram. Processes described in choreographies may also be executed on the same machine. Thus, choreographies also allow both local and remote execution.

Having regarded the classifications, a subprocess is defined as follows: *A subprocess is a process with a single logical entry and zero or more autonomy properties*. The concrete autonomy properties can be chosen from the autonomy degrees presented in Sect. 2.1.

4 Related Work

Related work on subprocesses discusses modeling aspects and runtime aspects of subprocesses. First, we present approaches mainly dealing with modeling aspects of subprocesses (Sect. 4.1) followed by Sect. 4.2 discussing runtime aspects. The overall distinction to our work is, that all these works discuss these aspects under the assumption of a traditional subprocess definition.

4.1 Model

The work of Vanhatalo et al. [VVK08] detects single-entry-single-exist regions (SESE regions) in workflow graphs. They define subprocesses as one SESE region and plan to use their work to identify common SESE regions across multiple processes to create a repository of reusable subprocesses.

YAWL [vdAtH05] supports modeling tasks as composite tasks. The execution semantic of a subprocess is that it gets started as soon as the composite task is started. The subprocess is canceled in case the task is canceled. As YAWL does not support compensation, the subprocess cannot be compensated.

Kiepuszewski et al. [KtHvdA03] focus on the control flow in workflows and defines subnets. They do not regard interactions between partners and lifecycle subordination.

Fragments are parts of business processes, which are stored in a repository and used at business process modeling [LD99, KWK05, ML09, EUL09] or executed as a part of a complete process [KL06, BD99, EUL09]. Whereas subprocesses have a defined entry and a defined exit, fragments are arbitrary parts of business processes. Lindert et al. [LD99] use autonomy in the sense that "the organizational unit can autonomously describe the fragment and enact the fragment". Lifecycle, data sharing or other autonomy degrees are not regarded. Up to now, fragments for business process modeling are not annotated with autonomy properties, which hampers reuse of SESE fragments as subprocesses. Fragments used for execution have predefined properties stating that they are part of a global model and thus implicitly define their autonomy.

The workflow patterns [vdAtHKB03] use "subprocess/activities" in the context of parallel branches of a workflow. In pattern 12 "Multiple Instances Without Synchronization", the authors describe the possibility to "kick-off" a new workflow instance without additional synchronization and control by the caller, which corresponds to "send only" in Fig. 2.

Both Service Interaction Patterns [BDtH05] and message exchange patterns [NvLL08] present how multiple services may interact which each other. Both works do not treat autonomy.

Reijers et al. [RMD10] investigate whether using subprocess during business processes design helps to foster understanding of complex processes. The authors provided evidence that this is true. They regard SESE subprocesses, but do not investigate the influence of different autonomy degrees.

Regarding process autonomy, von Riegen et al. [vRZ07] discuss the supervision of partner processes. The work lists different levels of enforcement, formats and communication patterns. Offering such properties introduces subordination to a participant. The properties itself are part of the view category in the autonomy taxonomy presented in Sect. 2.1. Leymann and Roller [LR00] outline a spectrum "from the subprocess being absolutely autonomous to the subprocess being totally controlled by the parent process", but do not provide a concrete spectrum. The WfMC reference model [Hol95] does not provide information about subprocess autonomy.

Veijalainen [Vei07] discusses autonomy in mobile P2P environments. There, autonomy is defined as the impossibly to control the behavior of an entity in the context of interactions.

In our work, that kind of autonomy is reflected in the control flow definition of a subprocess. Starting from that definition, an operating guideline can be generated [LMW07]. Using this operating guideline, the autonomy with respect to communication can be derived. Our model of autonomy (presented in Sect. 2.1) goes beyond the pure interactions and lists properties such as life-cycle dependency.

BPEL4WS 1.1 [BPE03], the predecessor of WS-BPEL 2.0 [BPE07], allowed a compensation handler to be specified at `process` level. This property has been removed in WS-BPEL 2.0, as the committee decided to remove any dependency on specific coordination protocols [Ark04]. These coordination protocols are defined in the BPEL subprocess extension (BPEL-SPE [IBM05]). There, the subprocess capability is added to BPEL: a BPEL subprocess is a process with a single start activity and a logical single reply activity with a compensation handler enabling compensation of the whole process instance.

4.2 Runtime

The workflow data patterns [RtHEvdA05] present different possible variants of data sharing between a process and the called subprocess. The approaches range from no sharing to full access of the data of sibling subprocess instances and the parents's process data. The subprocess definition used by the work states, that a subprocess may have multiple entries and multiple exists.

The approach presented by Hagen et al. [HA99] uses events instead of a shared database to exchange data between a parent process and a subprocess. The events are also used to propagate exceptions across processes. These events trigger compensation of finished activities. Thus, the subprocess has full autonomy besides exception handling.

There are several late binding approaches, selecting and binding subprocesses at runtime. Marconi [MPS$^+$09] proposes an approach refining activities of a process at runtime with a subprocess. Worklets [AtHEvdA06] use subprocesses as implementation of tasks, where the selection strategy depends on context data.

In case a subprocess is a standalone process, it is instantiated by a single or multiple messages. In this paper, we did not focus on different instantiation semantics. A detailed discussion about process and subprocess instantiation is available in [DM09].

The work of Grefen et al. [GLDA06] deals with business process outsourcing and proposes an interface “CTRL” to control the behavior of an outsourced process. They list pause process, resume process, abort process and compensate process as example. These properties are part of our lifecycle control autonomy. The infrastructure presented in [GLDA06] can be used to realize our different degrees of autonomy.

Regarding the interplay between autonomy degrees, Kopp et al. [KML09] present that current coordination protocols are not enough to handle the case of an activity being on a path of two callers (MEME with multiple partners, case (iii) in Sect. 2.2.3) and having the lifecycle control dependency “Terminate” and “Compensate”.

WebSphere Process Server 7.0 [IBM10] enables the execution of subprocesses, whose lifecycle is bound to the caller.

5 Conclusion and Outlook

In this paper we presented a spectrum of subprocesses fathoming the area between traditional subprocesses and choreographies. We presented three classifications for subprocesses: autonomy, interaction and execution. These classifications can be used to classify existing works as well as classifying future work on process modeling. We excluded concrete implementations and concrete coordination protocols in this work. Our future work is to provide a survey on existing implementations and possible coordination protocols.

The main focus of our future work is on the interplay of different autonomy properties and the autonomy modeling in choreography models. In case a subprocess itself is a part of a process, the most interesting point is the interplay between compensation requests from callers and compensation of the subprocess by the process itself. Additionally, the relation between process autonomy and service level agreements has not yet been investigated. The presented autonomy classification provides a basis to start investigation of relations between service level agreements and process autonomy.

Acknowledgments

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Crossing the Chasm Between the Real World and Business Process Management

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Abstract: While agility is a core challenge in todays competitive business, software-based business process modeling and execution approaches often refer to strict and inflexible formalization. Complementary, we propose an extension of the business process model by integrating information from the Internet of Things to increase flexibility. Along with orchestration tools and knowledge worker support, new dimensions within the data and the business process model are supposed to significantly improve business process management.

1 Introduction

Half-value periods of competitive advantages shrink and competitive edges need to be adjusted permanently [PM85]. Agile business processes are hence needed. For that, transparency over real world activities is important. The integration of information in a fast and value-directed way can contribute to business improvement. So, an integrated concept for information retrieval, analysis, and processing is required.

While a lot of today's research deals with business process automation, our concept is based on the assumption that not each and every business process can be automated. To put this into perspective, our concept hence reflects Goldratt's theory of constraints [GC84]. Complex business processes require knowledge workers that analyze and synthesize information to develop appropriate solutions. Though full automation is not feasible, knowledge workers have to be provided with all relevant information and powerful support concepts such as conducted business process orchestration. So, our concept focuses dynamic business processes. Though a lot of research has been performed in this field, a lack of acceptance can be constituted as the underlying data basis has never been sufficient [PvdA06]. In this paper, today's information blind spots during business process design, planning, and execution will be revealed. Then, the data basis will be leveraged by integrating reality based object information from the Internet of Things (IoT). Consequently, a systematic concept will be introduced that transforms the IoT-based extended data model into an extended business process model. The enhanced models, finally, enable agile business process management, which, in our concept, implies the fast and flexible (re-)composition of business processes. Thus, components of this consistent and homogeneous concept are presented in detail. Finally, we try to close the gap between pure efficiency and pure responsiveness and to improve the performance of business processes.

2 Initial Example

Motivation. In industrial manufacturing, maintenance management requires maintenance service managers to define general maintenance services and to plan specific process instances according to the respective customer needs.

Status quo. The daily job of a maintenance manager demands industry domain knowledge, process management skills, the analysis and synthesis of information, as well as decision capability. When a customer calls a service provider, information has to be put in context. The employee investigates if designed maintenance processes fit to the environmental context, the specific customer situation, and to resource availability. Business process instance planning needs to be adapted accordingly. For instance, if a formerly unknown error occurs, the recommended maintenance process needs to reflect this fact. The resulting customer-specific maintenance services requires the continuous adaptation of pre-defined processes. Particularly in such a change-ridden environment, adaptation may be even necessary during process execution, e.g. if an unexpected error shows-up during the on-site visit of a maintenance engineer. All in all, the number of process instance variants increases over time. In addition, the pre-designed master services have to be re-revised as well, if process instance specifications continuously deviate from the pre-designed master process; e.g. if process delivery permanently exceeds limits, the predefined process time needs to be adjusted. Moreover, changes such as in legal regulations, may require to re-engineer business process design. So, design of master maintenance services is also exposed to continuous change, albeit not as often as instance variants.

Opportunities. Transparency is a key prerequisite for any agile business process management activity. By using IoT-technology, real world information can be included into business processes. For instance, smart tags attached to devices can send information in terms of working status and environmental conditions such as humidity etc. Respective information can then be used by the maintenance service manager for the specific process instance planning. Likewise, transparency over process deviations can significantly improve the design of master service processes. Moreover, business process models should be enriched to cover the IoT-based information input and reflect any potential process changes. Transparency is relevant to reactive and proactive measures. The earlier a lead indicator can be identified and communicated, the better processes can be adjusted.

3 Blind Spots and Related Work

To put our initial example into perspective, this chapter generalizes the presented challenges and opportunities. While business processes can be described as interplay of resources of different functional units by means of activities, business process models are expected to describe them on a meta level. Moreover, for business process instantiation, a process planning and execution system is required, which delegates and tracks activities in the scope of the business process model. In this chapter we systemize the findings of the initial example to identify two generic blind spots in business process models and to demonstrate the need for agile business process orchestration.

3.1 Blind spot I – Business Process Instance Planning and Execution

The lack of transparency and timely delay with respect to information that is relevant to business process instance planning and execution is enormous. For instance, information about the physical state of things and the current position of resources is often not up-to-date or not available at all.

The blind spots in business process planning and execution reflect the awareness of the environment. The IoT is a powerful infrastructure that can provide status information and increase the information value of the business process instance model. Tracking technologies enable the detection of environment state and changes thereof. The term IoT encapsulates a variety of sensor based technologies like RFID which provide event and status information to connect information systems and the physical world [Mat05]. Such real world integration still lacks means to connect such devices and integrate them in a standardized way into existing business process management systems. We see two demands: standardized collection and business oriented processing of the accessible information. [Sch07] proposes smart tags to create a general object memory, standardizing the storage and distribution of information collected during the lifetime of a product. The IoT generates high value event streams of data which need to be organized and processed. [Luc02] describes complex event processing (CEP) as useful approach to find patterns of interest in streams of real world information, enabling the aggregation of such information to events. Such events need to be contextualized with respect to the business. [VAESW08] proposes an extended modeling approach, which integrates event and process modeling.

3.2 Blind Spot II – Business Process Design

A lack of transparency is often identified while (re-)designing business processes. Control instances on the process execution, beyond mere approval of task execution, are necessary to observe the deviations and the reliability of the designed generic process models.

Again, IoT is the needed transparency driver for (re-)designing business processes such as master maintenance processes. Generation of new business processes as well as re-design and re-engineering is a well known demand [KG95] that is supported by numerous methodologies [MWC06]. Still, most methodologies are realized based on project teams or consultants which are not integrated in the actual execution process in a company, but try to understand it based on domain knowledge, interviews, and observation. These processes are triggered by the decision towards organizational change, e.g. by implementing a new IT-infrastructure which is no optimal foundation for the realization of continuous process optimizing redesign and re-engineering life-cycles [KGT95]. The integration of IoT information and process performance on design level is an important aspect. [SS10] propose an extended model to integrate internal and external information into the business process design. Moreover, [HHF06] demonstrate that the process redesign and re-engineering can be directly supported by integrating process execution information. Such information has been described in the previous section as generated by the IoT and included into the extended modeling approach [VAESW08].

3.3 Business Process Orchestration

Agility is no core capability of business process management, which, finally, leads to a mismatch between reality and model.

Different examples to automate process flexibilization exist, e.g. change patterns [WRR07] or business rules [vEIP08]. Knowledge involvement into event response and process execution is a key aspect in today's business environment [Rem02]. Different efforts of blending research results from the domain of knowledge work with business process management exist. Examples of these efforts are a context aware business process management system providing different interaction interfaces [Cha04] or a framework enabling individualized process execution [LBC09].

4 A Weaved Net of Bridges and Orchestration

4.1 Overall Concept

The changed understanding of the business processes modeled in IT systems results in business process design, which is increasingly consistent with real world challenges by realizing all the aspects depicted in Figure 1. The basic order of the illustrated concept is fivefold and comprises the business process models and the business process instance models.

The resulting process of model transformation starts on the mapping of real world representations in the business process model:

- IoT-information increases the number of perceived attributes (red funnel / see Sect. 4.2)
- Attributes get assigned to the business process design (arrow F / see Sect. 4.3).

  The business process model results in an extended business process instance model:
- Model assigned attributes are linked to process instance models (blue arrows / see Sect. 4.3).
- Resulting instance model attributes get then nurtured by IoT-based specific data sets (red dashes / see Sect. 4.2).
- Bridges symbolize knowledge worker support by means of orchestration and decision support (see Sect. 4.4).

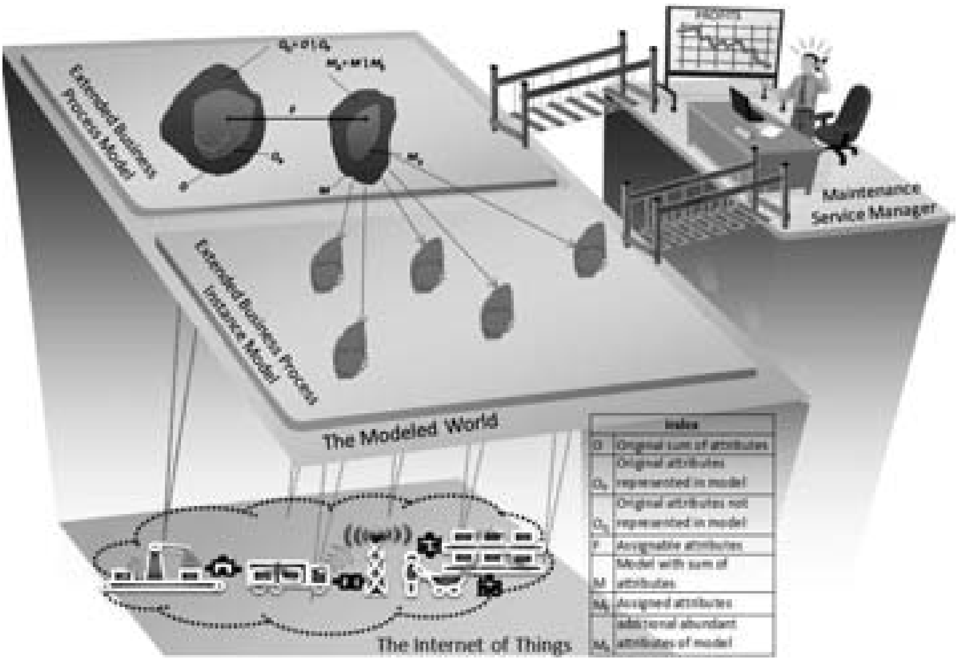

Figure 1: A Weaved Net of Bridges and Orchestration

4.2 Blind Spot I – Enlightened

Awareness of the environment is one of the key prerequisites in our solution concept. Particularly during business process instance planning and execution, real-world information is needed for optimal process performance. Accordingly, relevant information retrieval rules have to be identified. In our concept, events are indicators for a change of state in the environment and represent a core component of information classification. In the following we describe our definition of event categories in the IoT environment and their impact on agile processes, described in more detail in [SS10].

Potential relevant events are events generated out of the real world along a pre-defined set of input information sources. By using CEP, relevant events will be identified, structured, and aggregated out of the potential relevant event pool. So, the information quantity gets transformed into valuable information quality. Relevant events, then, present the information source for event subscribers. The resulting events, are input parameters for agile business process adjustments, which can be performed on a business process design or instance level. In general, an event taxonomy is introduced that ensures that all events are classified in a way that they can be integrated into business processes. The environmental blind spot is hence transformed into event based inputs for the extended business process model and hence enables agile business process management.

4.3 Blind Spot II – Enlightened

The design phase of agile business process management is an ongoing effort of business process improvement, re-engineering, and creation. An effort based on information that is extracted and generated during the process instances. IoT events are blended with process status change logs capturing changes in the process execution and the activity tracking implemented in the Human-Process Interaction Platform (see Sect. 4.4).

By associating process models with relevant execution data and assigned events, processes can be analyzed with respect to their efficiency. Efficiency addresses not only the execution time of processes, but additionally the variance of a set of actual process executions and involved variance triggers. As a result decisions towards process redesign and re-engineering can be made. For our modeling approach such decisions especially imply the transfer of information between the strict process model and the underlying knowledge base. As such elements of the knowledge base are upgraded to actual process steps or downgraded to recommendations in the knowledge base. Depending on the impact of these information transfers the dimension of a redesign or a re-engineering can be observed. Beyond redesign and re-engineering the identification of new processes can also be supported by the analysis of the actual execution data. All in all, we achieve an enhanced business process model on a design level that builds the foundation for adequate attributes within business process instances.

4.4 Conducted Orchestration

Process change involves the adaptation of a process. We discussed different methods to automate process change (see 3.3). Nevertheless, these methods are not applied in reality as knowledge bases on process variance are small and their integration into existing models is a tedious task. The necessary knowledge is often only accessible through people's expertise. We define the manual adaptation of a process as conducted process orchestration. For this task we will describe a twofold approach focusing on modeling and adaptation of business processes.

Modeling core process and variance. The modeling integrates process modeling and a connected knowledge base. Our dictum is the separation of areas of variability from a core process. The core process is modeled by standard approaches, e.g. petri nets or π calculus based. For each human activity involved in the process a link to a knowledge base exists, which is realized as ontology. The ontology collects problems that occurred during the respective step of the execution process, decisions which were made, resources used, and subtasks which were created.

Human-Process Interaction Platform. The individual execution of process tasks needs to be made explicit by providing a dedicated environment. Several concepts have been developed in the domain of computer supported collaborative work which suite this demand. Our approach is linking a workbench for work organization with a whiteboard for task-specific service and information composition. Thus, we can contextualize user work with respect to processes they belong to and the information consumed and created. As visible in Fig. 2 the individual is aware of the process he is embedded in (Nr.1), is informed about events which affect the business process, related best practices (Nr.4), and has a workspace which allows the interaction with the process (Nr.2 and 3). The effect: the difference between the role of a process planner and a process executor vanishes. So, the business process executor being empowered to re-plan becomes part of the business process instance definition and planning. Re-planning is done permanently in industry settings, but it is not reflected in the business process instances due to the lack of necessary expressiveness. Our proposed extended modeling used as empowerment of the executor enables agile process execution that is mirrored in a business process management system.

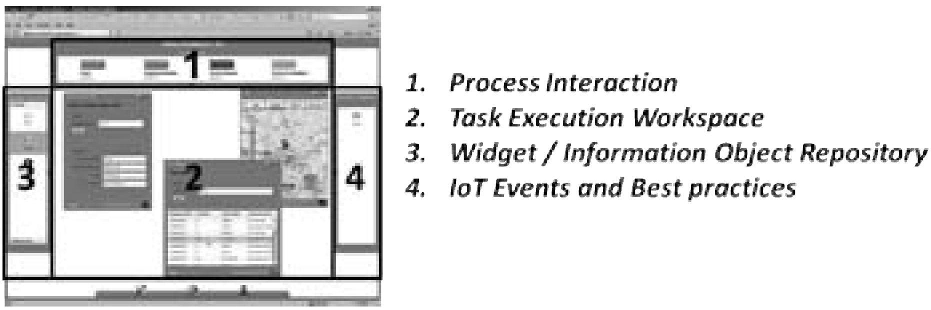

Figure 2: Human-Process Interaction Platform

5 Conclusion

The proposed concept of the weaved net of bridges and orchestration is a systematic approach towards agile business process management. It enhances the business process model in terms of IoT events and empowers knowledge workers to interact with the business process by conducted orchestration. Additionally, our concept enables ex-post analysis of process instances applicable in a business process improvement lifecycle. In sum, the performance of business process instances as well as the design of business process models can be improved. Thus, the chasm in terms of information divide between the real world and knowledge workers is bridged.

Further work is needed in the development of the presented components and the architecture. Within our research project prototypes have been developed that exactly address these challenges (e.g. Fig. 2). Moreover, the concept will be further refined and realized in an integrated overall architecture. The latter, finally, will be used to evaluate the overall applicability of the described approach. To demonstrate a broad applicability, various tests in different industry domains are in the scope of our project. The technical implementation as well as the demonstration in real world environments are hence in the scope of our daily work on the way to bridge the chasm towards agile business process management.

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On the Notion of Context for Business Process Use

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Abstract: In today's distributed and dynamic business environment companies and their business processes are frequently subject to changes, requiring the ability to continuously evolve business processes in a flexible and dynamic way according to changing external conditions. Taking flexibility as the ability to react to changes by adaptation, it appears appropriate to take the environment, where a change occurs, into account when designing business processes. We propose that the notion of context is key for achieving this objective. Based on a multiperspective analysis we derive a conceptualization of context for business process use that may help to improve the understanding of the notion of context for its integration in BPM.

1 Introduction

In today's distributed and dynamic business environment companies and their business processes are frequently subject to changes. As a result of global and networked markets, individual demands, new distribution channels, etc., organizations increasingly have to face unforeseen developments and a higher complexity of their business processes at the same time, which makes it difficult to constantly align the company´s processes with changing external conditions. The ability to continuously evolve the specification and implementation of a business process in a flexible and dynamic way therefore often constitutes a highly competitive factor [BK03; KB05].

While there is consensus on this apparent need for flexibility in the literature, there is no common agreement on how to achieve this objective of flexible or adaptive business processes[1], which has led to a high amount of research in recent years [cf. e.g. So05; GP00; RSS06; KB05; Aa06]. At the implementation level, the service-oriented architectures (SOA) paradigm appears to be a promising approach as it "provides a flexible architecture that unifies business processes by modularizing large applications into services" [PH07]. Services are platform-independent, standardized pieces of software enabling their easy integration and use in multiple environments.

[1] In the literature, the terms flexibility and adaptability (among other terms) are typically used synonymously.

At the levels of business process (re-)design and monitoring, however, there is still a lack of appropriate methods for modeling and governing business processes in a more flexible way in accordance to their environment. It has been frequently proposed to make use of technologies and concepts taken from the Semantic Web approach to improve flexibility [BHL01]. These – often referred to as *semantic* – technologies are used to enable the provision of previously implicit knowledge about the meaning of domain-specific concepts in an explicit form which is usually achieved through (ontological) metadata annotations. In case of business process management (BPM), this approach has similarly been proposed by some authors arguing in favor of a Semantic BPM (SBPM). SBPM combines Semantic Web Services (SWS) and BPM with the objective to increase the degree of automation of business processes and to bridge the business/IT gap [cf. e.g. He05; HR07].

However, taking a closer look at the understanding of flexibility, this appears not sufficient. In general, flexibility is described as the ability to react to changes by adaptation [So05]. More specifically, business process flexibility can be defined as "the capability to implement changes in the business process type and instances by changing only those parts that need to be changed and keeping other parts stable" [RSS06].[2] This understanding implies that business processes are *aware* of the environment they are designed for, i.e. it has to be known what parts of the process have to be changed and which parts are to be kept stable, and it has to be noticed when a change is necessary. This in turn suggests taking the environment, where a change occurs, into account when designing business processes. The notion of awareness of an entity`s environment, in turn, can be closely related to the notion of context. *Context-awareness* refers to discovering and deploying context information, where context – in its most generic definition – is understood as "the interrelated conditions in which something exists or occurs" [MW10; CK00]. Information on a particular context therefore refers to information that is relevant to a particular entity in a particular situation.[3] Adding context to business processes thus may help to not only explicitly specify the *meaning* of process elements, but their *relevant meaning* in view of certain surrounding conditions.

Context, though, is a polymorphous term that has been explicitly used in various fields and disciplines, such as psychology, philosophy, linguistics, artificial intelligence, etc. [BB05]. Initially, context is a concept referring to language use and thus has been intensively studied in linguistics. In IS research, the notion of context gained particular attention in the fields of mobile and ubiquitous/pervasive computing. As regards BPM, the use of contextual information constitutes a new but promising approach [cf. e.g. RR06; Ro06; RRF08; Pl09; SN07]. The basic supposition underlying the use of context in all these fields of research is – as pointedly summarized by Davies and Thompson – "the acknowledgement, explicit or implicit, that organisms, objects and events are integral parts of the environment and cannot be understood in isolation of that environment" [DT88]. As business processes highly interact with their surroundings and usually involve a great amount of collaboration, it seems appropriate to also consider contextual values of meaning to improve business process flexibility.

[2] For a detailed analysis and discussion of the definition of flexibility cf. e.g. [GP00; So05].
[3] The notion of context will be discussed in more detail in section 2.

For integrating contextual information in BPM it is crucial to understand what context is, which contextual factors play a role, and how these can be used to improve process flexibility. For contributing to this issue, the purpose of this paper is first to assess the notion of context for business process use based on a multiperspective analysis of the term, focusing on the use of context in language and mobile and ubiquitous computing research respectively (section 2). Second, based on this analysis we provide a conceptualization of context by identifying six types of context relevant to BPM which may help to improve the understanding of the notion of context in this field (section 3). Section 4 concludes with a short summary and an outlook on future research.

2 The Notion of Context

The notion of context has been explored in many disciplines, increasing both the number of definitions and conceptualizations as well as the term`s ambivalence and vagueness at the same time. In the following subsection we analyze the notion of context from the perspectives of context in language use and in mobile computing scenarios. These two fields are seen as key areas for deriving a business process related understanding of context as the notion is rooted in natural language use and has been primarily used in mobile computing as regards IS research. Context is of a fundamental importance in these fields, resulting in a high amount of research and a solid foundation for assessing the notion of context as regards business process use. Based on this analysis, we derive an appropriate understanding of context for business process use based on related work.

2.1 Context from Language to Systems Use

From a linguistic perspective, context constitutes a fundamental aspect of the determination of meaning in language use that has been a topic of research since the 1920s.[4] Starting from Morris' semiotic theory as the theory of signs, linguistics can be divided into the three branches of *syntax*, which is understood as the study of "the formal relation of signs to one another", *semantics*, referring to the study of "the relations of signs to the objects to which the signs are applicable", and *pragmatics* as the study of "the relations of signs to interpreters" [Le83]. More precisely, syntax deals with the properties or structure of words and expressions, semantics with their meaning or content whereas pragmatics refers to *meaning in context* [Le83].

Hence, context can be primarily attributed to the field of pragmatics. Despite a long tradition of research and its importance for the derivation of meaning, there is however no common language-based definition of the term.[5] Often context is seen as the set of attributes or features relevant to the production and interpretation of utterances [Le83].

[4] As a precursor Malinowski (1923) is often cited: "a statement, spoken in real life, is never detached from the situation in which it has been uttered. […] the utterance has no meaning except in the context of situation." cited in [Wi04]. For an historical overview of context research in linguistics see e.g. [DG92; Wi04].

[5] This is pointedly illustrated by a quote taken from Asher (1994): "Context is one of those linguistics terms which is constantly used in all kinds of context but never explained", cited in [Fe04].

These attributes are relevant as the meaning of a sentence or utterance can vary depending on the situation in which it is analyzed. Accordingly, Duranti and Goodwin conceive context to be a frame surrounding the object of interest, called *focal event*, that describes a field of action in which this object is embedded [DG92]. Thus, context provides additional background (non-focal) information contributing to the understanding of situations. However, the contextual attributes of the respective field of action are mostly not or ill-defined. It is common to include implicit and explicit information about roles, the involved people`s assumptions and beliefs about temporal, spatial, and social settings, their state of knowledge and all verbal and non-verbal actions related to the respective situation [Le83; Au09]. Different classifications exist, separating contexts into objective, subjective, and social aspects [Fe04] or into linguistic contexts, physical surroundings, the social situation, common background knowledge, and the channel of communication [Au09]. It is important to note that the features of context are determined from the perspective of the entities under consideration and in a specific situation involving certain activities, thus making context a subjective and interactive concept that depends on the respective actors and activities involved [DG92; Fe04]. Moreover, context always refers to an activity or event under consideration, making it a relative concept that depends on its use [DG92; BB05].

In IS research, the notion of context has been investigated in various fields, receiving particular attention in mobile and ubiquitous/pervasive computing and leading to a plethora of definitions and understandings. The most widely used definition by Dey and Abowd describes context as "any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves" [DA99]. Although this definition is very generic, it again highlights context as a notion of interaction providing additional information on a particular situation or activity. A more specific definition is provided by Schmidt et al. who perceive context as the "knowledge about the user's and IT device's state, including surroundings, situation, and to a less extent, location" [Sc99]. As Dey notes, these definitions are typical for the field of context-aware computing where context is either paraphrased by means of synonyms, such as *environment* or *situation*, or by enumerations of examples of possible context factors [De01]. The term context-awareness was initially coined by Schilit and Theimer to describe the ability of applications to "discover and react to changes in the environment they are situated in" [ST94]. Hence, an application is context-aware if it is able to take advantage of contextual information that is of interest to a particular entity. This context information typically includes information on (i) the computing context, such as network characteristics, applications, etc.; (ii) the user context, such as roles, beliefs, etc.; (iii) the physical environment, such as lighting, nearby objects, etc.; and (iv) the time context, such as day of the week, time of day, etc. [SAW94; CK00]. Schilit et al. summarize the important aspects of context by *where you are*, *who you are with*, and *what resources are nearby* [SAW94].

2.2 Context for Business Process Use

The field of context-aware BPM is still in its infancy [RRF08]. Whereas common definitions and categorizations from related fields serve as a theoretical basis, they cannot be identically applied to business process use. In the following, we highlight two early works in that field which are considered relevant for this paper. Rosemann et al. introduce a context framework for process modeling to enable a more flexible and context-oriented design of business processes [Ro06; RRF08]. Their conceptualization of context consists of an onion model including four layers of context: (i) immediate context, referring to all aspects that are essential for the execution of a process, such as required data, applications used, etc.; (ii) internal context, including the immediate organizational system in which the process is embedded; (iii) external context, comprising all external elements relevant to the process, such as competitors, suppliers, customers, etc.; and (iv) environmental context, constituting the outermost layer of the model including factors that are still relevant but outside of the organization's direct network, such as socio-cultural or political-legal issues. Their work constitutes a seminal contribution towards contextualizing business processes. Also, Saidani and Nurcan argue in favor of context-aware process modeling [SN07]. Their work illustrates the relevance of context-related knowledge for process design and includes a four-step model for integrating context knowledge comprising (1) context elicitation, (2) categorization, (3) adaptation and measurement, and (4) business process instantiation. The authors propose a categorization of context knowledge into (i) time-related context, (ii) location-related context, (iii) resource-related context, and (iv) organization-related context. Their work is based on their earlier research on role-based process modeling and thus mainly emphasizes the actors involved in and relevant to a business process.

In consideration of the above mentioned views, we conclude the following general characteristics of the notion of context. (1) C*ontext describes a set of states*; it does not represent an individual concept but denotes a set of several conditions framing an object of interest. It refers to the whole set of interactions and relations of entities and activities in a particular domain. (2) *Context is subjective* as it highly depends on the activities and objects under consideration and the entity perceiving it. Therefore, its understanding also highly depends on the respective domain of interest in which it is used. (3) *Context is relative*, i.e. context is not autonomous but always related to some activity or event. This means that contextual information highly depends on its relevance for the intended use. Hence, context-awareness of business processes can be understood as the detection of and appropriate reaction to events that are relevant to and might affect the execution of a process. A business process is context-aware if contextual factors – factors that might cause such an event – are made explicit for their use in BPM in order to take advantage of this explicit context information for dealing with changes. Context might be crucial for achieving a higher degree of process flexibility as context accounts for the environment of the process and changes often cannot be anticipated in advance, particularly in frequently changing business environments. Based on the generic definition of context by Dey and Abowd, the following understanding of context for business process related tasks can be derived: Context is any information that is relevant to and might affect the execution of a business process. This information includes aspects of the process itself, the business environment in which it is embedded as well as any other entities that interact with the process.

3 Conceptualizing Context for Business Process Use

In the following we present a possible conceptualization of context for business process use that may serve as a basis for the understanding of context in that field and the identification of contextual aspects affecting business processes. Different to Rosemann et al. [RRF08] we think that an onion model is not appropriate in this regard due to the following reasons. First, as the authors already indicate the onion model suggests relevancy based on proximity, i.e. the elements of the outer layers are considered less relevant than the inner layers. This may seem true in case of immediate context which is certainly most relevant to the process itself. However, we consider environmental issues, such as social or political factors as relevant as, e.g., the organization's competitors. This is highly dependent on the process under consideration. In this regard it may also be argued that the inclusive structure is also based on impact, i.e. the outer layers influence all elements of the inner layers. Again, this appears too restrictive as context relations may also be bilateral, e.g. internal context factors may also influence external ones. Instead of this layered, concentric architecture we conceive these aspects rather to be highly intertwined and affecting each other in mutual relationships. Second, context is a highly subjective and user-centered notion as proposed in a similar way by Saidani and Nurcan [SN07]. However, the user only plays a minor role in their model. We assume that the people involved in the entire life cycle of BPM as well as their behavior and characteristics play a major role in the organization as a *living system*. Third, the onion model is not eligible to represent relations and interactions between the context factors. Based on the analysis above, however, we take context as a notion of interaction describing the relations between objects and the entire set of contextual variables forming an event.

Based on these observations and the analysis of context in section two, we propose a relation-based conceptualization of context that is applicable for the use in BPM. This understanding is based on six context categories as described in the following and illustrated in figure 1.

Domain Context refers to the superordinate domain in which the focal event or object is embedded. In our case, this refers to the business environment in very general terms which is required to set the outer realm restricting relevancy. This is crucial as we have seen that the requirements for contextual information vary between different fields of application.

Business Process Context denotes the elements directly related to the business process. Beside the process itself, this may include several contextual properties, such as e.g. process characteristics, the control flow, specified goals, required resources, organizational units involved, etc., and is directly related to each of the following context types.

Internal Organizational Context includes information about the organization which the business process is designed for. This information predominately comprises characteristics of the organization, such as strategy, number of employees, business area, organizational structure, etc. For the case of interorganizational processes, this may also include the whole network of organizations involved in the execution of the process under consideration.

External Organizational Context has to be delineated from the former type as it refers to information about all external conditions of the organization, i.e. those aspects that are out of the organization's immediate control but are relevant to and affect the business process. This predominantly refers to the market environment, including elements such as competitors, customers, suppliers, market conditions, etc., as well as e.g. political, cultural, or location-based aspects.

Information System Context refers to the entire IS infrastructure in which the applications implementing the process are embedded. This may include all related pieces of software and hardware enabling the implementation of the process as well as all other applications for user support involved in the execution of the process.

User Context includes all actors involved in (re-)design, execution or monitoring of the business process under consideration. This type of context may include profile information, such as qualifications or the social background of the user, but may also refer to roles, tasks, and responsibilities of the actors involved in achieving the process goals.

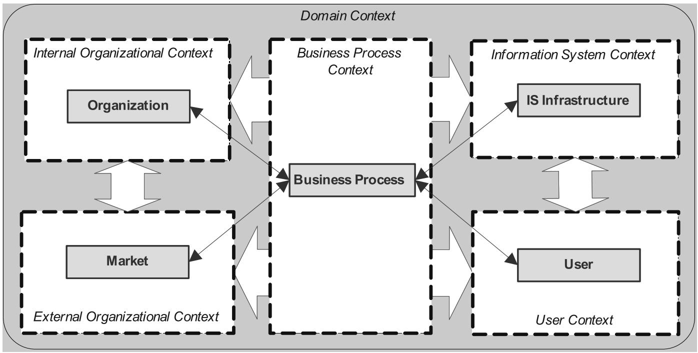

Figure 1: Context types and their interaction

As indicated in figure 1, these individual categories are highly intertwined and interact by means of the relationships among the single entities in a business domain. As pointed out in section two, context can be understood as a frame surrounding the relevant object of interest. Correspondingly, each category centers on a *focal element* (in light blue) that is related to the other core elements within the respective category. For instance, the *user* is seen as core element for the *user context*, whereas *external organizational context* is centered on the term *market* here, denoting all external participants in the environment of the organization. This conceptualization is based on a relation-oriented understanding of context as the elements forming the context relevant to a business processes are perceived to stand in direct or indirect relations to each other.

4 Conclusion and Outlook

„[C]ontext knowledge will enable future PMS [Process Management System] architectures to discover, use and learn from process changes in an intelligent manner, and will thus make them adaptive to flexible processes." [Aa06]

To make this vision come true a lot of research work still has to be done. Although the notion of context has been explored in a variety of disciplines and from a number of different viewpoints, a common understanding of the notion of context for business process use is still lacking. We present a conceptualization of context comprising six key context categories which appear relevant for contextualizing business processes. These categories are based on the interaction between a business process and its environment. Following up on the issue of process flexibility as addressed in the introduction of this paper, the proposed conceptualization may be seen as a preliminary step for indentifying and classifying possible context factors as well as their representation to allow for better dealing with changes in the process environment. By attaching explicit context information to the process, changes can be seen in a *higher context* enabling the more flexible adaptation of relevant and affected processes to these changes.

In order to prove the benefit of the proposed conceptualization, a validation based on example cases and the application of the model is further required. Moreover, future works should focus on how contextual factors can be identified in particular business environments and how context can be explicitly modeled for business process use. Again, existing literature in related fields of research may assist in achieving this objective [cf. e.g. SL04]. In addition, it must be investigated how context information can be retrieved, stored, and provided for its use in BPM. It should be analyzed how context models may be integrated into existing process modeling techniques and how context information may be effectively used to increase the flexibility of business processes. Besides process design, context-awareness appears to be a promising paradigm for all aspects of BPM enabling future business processes to better *interact* with their environments.

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