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Business Process Support for Collaborative Knowledge Workers

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Abstract

In developed countries knowledge work is the ongoing predominant type of work based on a social and economic change from an industrial society towards a knowledge-based, post-industrial society. In their daily business processes, knowledge workers like doctors, engineers or freelancers cope with demanding situations they usually solve by leveraging their distinguished mental skills and experiences. In doing so they usually work widely autonomously, often in multiple contexts, and so their daily workload is influenced by dynamic factors like time, costs and resources. As a part of their jobs knowledge workers frequently take care of resulting coordination issues as well as they increasingly work mobile and collaborate remotely together with other workers these days. In doing so they generally rely on a variety of available supporting software respectively communication channels which often results in unpleasant circumstances. Information like documents or e-mails are distributed and unlinked, misses its contextual relation and an overall state of progress is hardly accessible.

As a result a general lack of appropriate, contextual and process-related support impedes the reutilization of elaborated solutions as well as the continuous improvement of existing business processes. In this context business process management systems have been steadily advanced to improve the central, process-related support of business processes. But unfortunately these systems generally rely on the separation of planning and enactment of a business process according to Taylor's scientific management principals. Knowledge workers' business processes requiring emergent, unimpeded collaboration stretch these systems to their current limits. Therefore this thesis investigates the very nature of knowledge work and its involved knowledge workers, to evaluate the requirements as well as possible technologies to increase the contextual support of today's knowledge workers.

Acknowledgement

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Contents

1

Introduction

Knowledge worker productivity is the biggest of the 21st century management challenges.
In the developed countries it is their first survival requirement.

Peter F. Drucker (1909 - 2005),
distinguished writer, professor and self-described "social ecologist".

Globalization and the sweeping progress of information and communication technology (ICT) have significantly changed companies' economic competition situation for the recent decades. Markets are globally connected today and thus, customers can choose between a variety of products and services that have never been offered to such an extent before. Consequently customers' expectations have naturally risen in respect to price and quality levels. Furthermore, currently successful products can become quickly replaced as new ideas, business models and technologies are developed faster and in a larger quantity. Based on high competitive constraints and the resulting shorter product life cycles, companies have been compelled to rethink the way they actually develop, produce and offer their products and services. Therefore many companies have increasingly focused on optimizing their business processes, expecting to reduce operational costs on the one side and to boost quality and quantity of products or services on the other side.

These aspirations ground on the observation that each product or service companies offer, is to be considered as the output of activities performed in a meaningful order. Thus a *business process* denotes the elaborated coordination of human activities and corporate resources to achieve a customer-oriented business goal [1]. As a result the research field of *business process management* (BPM) has logically received intensified attention by professionals and researchers in the areas of economic sciences and computer science. The field aims on customer-oriented alignment and *includes concepts, methods, and techniques to support design, administration, configuration, enactment, and analysis of business processes* [1].

Although there are early contributions for a process orientation in organization and management [2], the business perspective of BPM has its main roots in a process orientation trend taking place in the early 1990s as globalization increasingly became a pervasive topic as well. By publishing their seminal work *"Reengineering the Corporation"* in 1993, Michael Hammer and James Champy encouraged a controversial discussion as they provocatively proposed the radical and fundamental redesign of all corporate end-to-end business processes to increase companies' efficiency and effectiveness [3]. Although their radical redesign approach was later qualified – incremental and evolutionary improvements are often more promising [1] – their approach set the foundation of an accepted insight that business processes are supposed to be constantly reviewed and optimized to secure entrepreneurial success in today's faster changing world. Therefore the *BPM lifecycle* exposes the idea of a constant optimization of business processes based on the phases *design*, *configuration*, *enactment* and *evaluation* (cf. Figure 1.1).

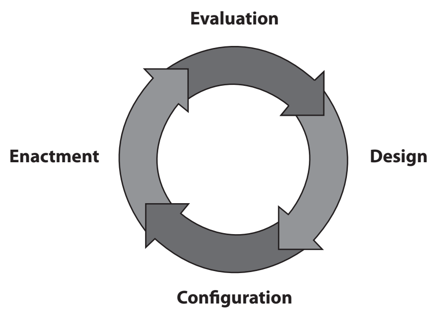

Figure 1.1: The business process lifecycle, based on [4]

The lifecycle is to be entered in the design phase addressing the business-related analysis, development and *design* of business processes. After a successful design phase, processes are to be implemented and *configured* in the corporate environment. This is usually realized by the utilization of technologies as well as deployed organizational structures, procedures and regulations. After a successfully established implementation, business processes are subsequently *enacted* by involved workers and performed to generate its desired corporate benefits. Grounding on a conscientious process monitoring, experts can *evaluate* the processes' quality in a last phase afterwards. Possibly drawn conclusions in the last phase can restart the lifecycle again and business processes may be adapted or even entirely redesigned.

From the perspective of computer science, the BPM community focuses on the support of people in every phase of the BPM Lifecycle by the usage of information technology (IT). Though, traditionally many business processes are still not accompanied by a dedicated information system, instead processes are enacted and driven by the companies' employees as well as corporate regulations and procedures. So people manually interconnect the process activities according to requested corporate regulations and procedures. But many corporate end-to-end business processes cross organizational borders like corporate divisions, subsidiaries or suppliers. A lack of end-to-end business process alignment often leads to local, counterproductive optimizations generating redundant work and thereby unnecessary costs. As an example, equal purchase processes could be performed differently in a company's divisions while an integrative process might yield efficiencies from scale and gained transparency (cf. Figure 1.2). But to establish an end-to-end support, a heterogeneous set of existing information systems, various data sources as well as process participants of different organizations, in different roles and with different backgrounds have to be integrated appropriately.

As a result the technology of a *business process management system*[1] (BPMS) has been introduced, a system dedicated to the automatized coordination of activities involved in business processes and to the integration of the established IT infrastructure into standardized, end-to-end business processes. Thereby local, vertical optimizations are to be reduced and organizationally, or even inter-organizationally, optimized processes to be

[1]Still widely known as *"workflow management system"* as well.

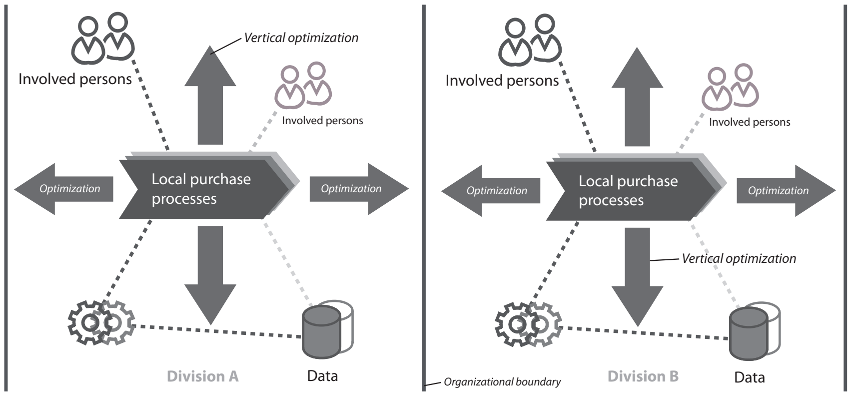

Figure 1.2: Counterproductive vertical optimization

implemented establishing an intended end-to-end support (cf. Figure 1.3). Connected with the BPM lifecycle, corporate requirements, procedures and regulations are mapped into explicit *business process models* during the design and configuration phases.

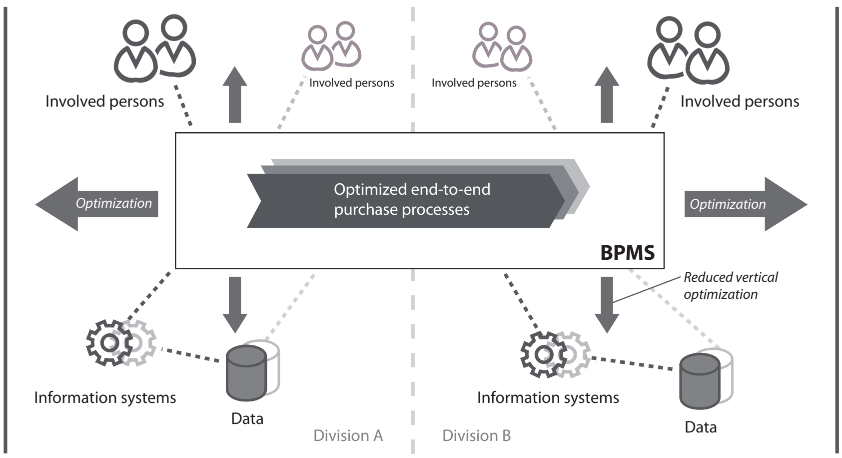

Figure 1.3: Horizontal process optimization by the usage of a BPMS

To establish such a support, the business processes have to be explicitly defined for a BPMS. Drawn graphically, a business process model basically contains abstracted process' activities, their inputs and outputs, their temporal relationships and optional branches.

Based on these deployed models, a BPMS allows the enactment of business processes and it supports the involved people accordingly. A BPMS automatically assigns activities and needed resources (e.g. data or applications) to participants and continuously updates participant's work lists. Additionally, a BPMS usually monitors the course of actions to enable business process analysts the assessment of process execution histories. Thereby possible issues and potentials can be identified in order to further improve the standardized processes.

1.1 Problem

The increasing possibilities to standardize or streamline production and administrative work by advanced technologies have already given rise to a structural shift of economies' value-adding jobs in highly developed countries. Standardized work can be increasingly automated by ICT or at least optimized in a process-oriented way. Furthermore this type of work is also increasingly outsourced as companies move production processes respectively standard services to low-wage countries in order to further cut operative costs.

But due to the global competitive pressure companies are concurrently encouraged to steadily offer more complex services and innovative products of a high quality to ensure long-lasting, sustainable entrepreneurial success. However the constant and qualitative innovation of new products in corporate research and development departments (R & D), or the provision of complex services generally depends on companies' best, full-fledged employees. Furthermore continuously rising legal and financial regulations have also steadily increased the need for experts taking care of compliance and quality issues. So as a result, today's companies progressively feature and offer a progressively higher share of knowledge-intensive jobs to secure their edge in quality, innovation and compliance as well.

In relation Pfiffner and Stadelmann highlighted this meta-sectoral structural transformation (cf. Figure 1.4) in highly developed countries based on their high standards of education and research [5]. In those countries the economies' main net product is going to be progressively generated by jobs characterized as versatile, sophisticated and especially knowledge-based. These jobs comprise the performance of work which represents the opposite of repeatable, routine work – the so-called *knowledge work*. Performed by *knowledge workers*, the successful accomplishment of knowledge work essentially depends on the workers' skills and experiences and – in general their *knowledge*. In connection with the increasing importance of knowledge work, economists naturally rate the significant advancement of knowledge workers' productivity as a key success factor for future economic growth. Drucker renownedly stated: *"Knowledge worker productivity is the biggest of the 21st century management challenges. In the developed countries it is their first survival requirement."* [6].

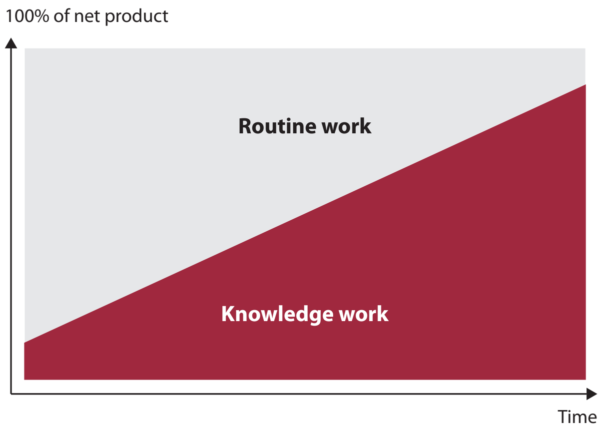

Figure 1.4: Meta-sectoral structural transformation, based on [5]

While Drucker presumably obligated mainly the members of economic sciences to improve knowledge workers' productivity, Davenport underlined the importance of IT support in relation to knowledge worker productivity: *"One of the things I will advocate [in this book] is that, when possible, it's a good idea to have computers mediate and structure the work of knowledge workers. [. . .] If you had to choose a single step to make knowledge work more productive and effective, this would probably be the one you should select."* [7]. So on behalf of the computer science community researchers are supposed to intensively address the challenge to optimally support knowledge workers, enabling them to perform their daily work effectively and efficiently.

Unfortunately there has been merely sparse academic research about how knowledge work is precisely performed in today's economic reality coined by fast technological progress and global interconnectedness. Various and also distinct definitions of knowledge work and knowledge workers have been published and revised by members of the arts. Sociologist Wilke stated that research about organized knowledge work is at its very beginning [8]. However it is widely accepted that knowledge workers rely on their individual expertise to perform their work.

Intuitively analyzed, knowledge workers generally determine the sequence of performed activities by their decisions and instructions based on their distinguished judgement. This first, coarse insight can be already rated as relevant: as knowledge workers generally perform activities in a coordinated manner in corporate environments, they are logically part of business processes as well. But in comparison to business processes which are traditionally analyzed, designed and implemented in relation to the BPM lifecycle, the course of a business process involving knowledge workers is believed to be determined by the workers themselves during the execution of the process. So currently available BPMSs are likely inappropriate to support knowledge workers: these systems generally rely on narrowly predefined, explicit process models which centrally determine the way people have to do their routine work and which are adaptable only to a certain extent during the run of a process.

As a consequence the majority of knowledge workers rely on a variety of standard software (e.g. word processor, web browser) in combination with a range of available communication and cooperation software (e.g. e-mail client) and corporate or domain-related software (e.g. corporate CRM[2] system). This circumstance implies they widely need to manually interrelate process-related information. Usually information is distributed in multiple data stores (e.g. files, databases) or it is encapsulated in used information systems. So knowledge workers currently face the situation that they unfortunately cannot rely on a process-related support which can be principally established for standardized work. In relation knowledge workers often suffer from an information overload as they have to manually pick out relevant information from massively increasing stocks of information [9].

Currently there is no approach which can entirely support knowledge workers during the performance of their work. As an additional consequence a comprehensive summary about

[2]Customer relationship management

work, which has already been performed (history) or about still pending tasks, is also not available. In addition knowledge workers have to independently manage their information about process participants, for instance, about people being involved in a shared context as well as information about the allocation of work packages. The lack of end-to-end support and process visibility can logically result in ineffectiveness and inefficiency like local, vertical optimizations as it is well known for standardized work. Finally, due to the general lack of context- and process-relation the conservation and reutilization of elaborated ideas, concepts and solutions is certainly hindered as well (no lifecycle support).

1.2 Contribution

This thesis' purpose is to examine how collaborative knowledge workers can be holistically supported by a generic and adaptive information system during the performance of their common knowledge work processes (objective I). Thereby knowledge workers' productivity should be significantly improved and existing issues like information overload should be reduced. Figure 1.5 illustrates such an ideal information system for the support of collaborative knowledge workers.

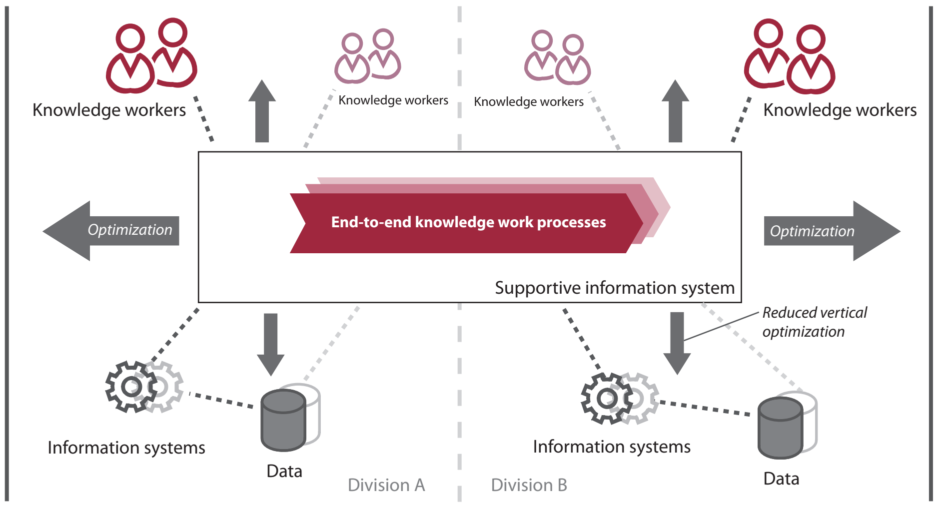

Figure 1.5: Ideal information system supporting knowledge workers

Underlining possible benefits the previously introduced engineers developing a robot could benefit from such an information system, which gathers and provides access to crucial information, communication and coordination assets in an interrelated and process-related manner. They would be enabled to perceive the overall state of progress and potentially arising issues can be identified. Furthermore context-related information could be centrally stored and preserved to be leveraged for future undertakings. This approach would be in line with the idea of constant business process improvement, illustrated in the BPM lifecycle (cf. Figure 1.1), although it does not decree explicitly predefined, imposed processes.

However an information system dedicated to the support of knowledge workers likely has to provide a highly multidimensional support in comparison to a BPMS. This results from the fact that knowledge workers are believed to actively determine the course of actions on their own. *In order to properly determine the extent and the type of support knowledge workers require, it is essential to understand their principles and the way knowledge workers generally perform knowledge work collaboratively (objective II)*. Thereby it has emphasized that both objectives are mutual dependent.

Thus an academical and profound foundation of the terms *knowledge work* and *knowledge workers* is provided in this thesis, based on a *study of interdisciplinary literature*. Generally, the foundation can be well leveraged for future research as it provides an understandable, solid base of knowledge work principles and compiles various academic resources and definitions. Furthermore these results are supposed to increase the general understanding of knowledge work and knowledge workers from the perspective of the computer science community. Qualifying the theoretical foundation, this thesis additionally provides *a case study* based on selected, representative use cases for collaborative knowledge work. Thereby common and distinctive dimensions are carved out whereby collaborative knowledge work use cases can be described more precisely. Logically the mentioned contributions are in line with the established *objective II*.

On the basis of detailed preliminary work, this thesis further provides a comprehensive and manageable *overview of the most important requirements* an information system, which is dedicated to the support of collaborative knowledge workers, has to satisfy. In relation to the requirements a conceptional lifecycle approach is additionally presented to holistically support knowledge workers. Generally the requirements as well as the presented approach can be leveraged to qualify existing ideas to support knowledge workers by unidimensional approaches (e.g. more communication support). Finally, existing *technologies are systematically evaluated* on their potential benefits to be leveraged for an information system supporting knowledge workers. These evaluations place related approaches into the context of this work and finalize the contributions regarding the targeted *objective I*.

1.3 Organization of the Thesis

Section 2 subsequently discusses the elementary terms of knowledge, knowledge work and knowledge workers. Therefore different involved research fields are presented to discuss the characteristics of the focal term of knowledge ensuing. Based on this preparatory work the focal term of knowledge work is properly introduced, an adequate definition is provided and the time-related course of knowledge work is discussed (i.e. knowledge work process). Following this, the term of a knowledge worker is defined and characterized to finally motivate their collaboration and its implications in theory. Section 3 logically builds on established results and deepens the theory by presenting three representative use cases for collaborative knowledge work. Moreover related use cases are shortly touched in relation to each use case. This allows the derivation of typical characteristics and dimensions of collaborative knowledge work whereby use cases can be generally differentiated along. Furthermore the characteristics and the dimensions round off the results of the preceding theoretical work and build an important foundation for the following sections.

Section 4 centrally presents a generic approach to support collaborative knowledge workers as well as focal requirements an information system needs to satisfy for a process-oriented support of knowledge workers. The qualitative requirements are derived from the previously established characterization of collaborative knowledge work on the one side and are completed by additional requirements proposed in related literature. Section 5 finally presents and evaluates current technologies considering the established requirements. Thereby technologies in the area of communication, coordination and content support are discussed accordingly. Precisely, the presented technology categories are *social software*, *constraint-based business process management* and *enterprise content management*. Lastly the thesis' results are summarized and incentives for future research are provided in Section 6.

2

Knowledge Work in Theory

A post-industrial society is based on services. [...] What counts is not raw muscle power, or energy, but information. [...]
A post-industrial society is one in which the majority of those employed are not involved in the production of tangible goods.

Daniel Bell (1919 - 2011),
sociologist, writer, editor and professor at Harvard University.

In *Landmarks of Tomorrow* (1959) the economist Drucker first popularized the term of a *knowledge worker* as he referred to an increasing set of work roles depending on education, skills and *"the ability to acquire and to apply theoretical and analytical knowledge"* [10]. In the following years he underlined the importance of this work type and he lastly began to claim that *"the chief economic priority for developed countries, therefore, must be to raise the productivity of knowledge and service work. The country that does this first will dominate the twenty-first century economically"* [11].

This section introduces knowledge work's principles and concepts as well as knowledge workers' common traits. Therefore involved research fields are presented in Section 2.1 to place the following discussion about the thesis' focal terms of *knowledge*, *knowledge work* and *knowledge workers* (Sections 2.2, 2.3 and 2.4). Finally *collaborative knowledge work* is discussed and assessed in Section 2.5 to ensure a smooth transition to next section presenting representative use cases.

2.1 Involved Research Fields

Knowledge work and knowledge workers have been an increasing object of interdisciplinary research conducted by members of various sciences and specific research fields for years. An overview of the mainly involved sciences is given in the following Figure 2.1. To provide a scientific placement and to underpin ongoing results some cornerstones of distinguished research is briefly presented in the following.

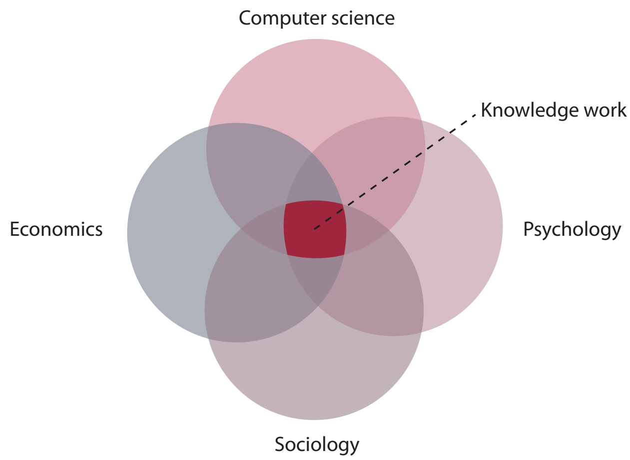

Figure 2.1: Involved sciences considering knowledge work research

The first who substantially described and quantified the knowledge-based industry was Princeton *economist* Machlup. He established today's common practice to consider knowledge as an important and even crucial business asset (called *"intellectual property"*). Thus he concluded sciences ought to consider a new type of workers, responsible *"for the entire spectrum of activities, from the transporter of knowledge up the original creator"*. Thus he accurately examined the creation, distribution and usage of knowledge in the U.S. economy. Publishing his results in 1962 he estimated the set of workers dealing mainly with knowledge to be roughly a third of the total U.S. labor in 1958 [12]. Moreover he observed the knowledge work sector to be rapidly growing: twice as fast as other sectors in the economy.

Besides the research in economics sociologists like Daniel Bell analysed the *sociological change* taking simultaneously place through the increasing importance of knowledge-based work. Linked to his examinations of the characteristics and growth of information- and service-based industries Bell already concluded in the 1970s that a post-industrial society was going to evolve [13]. In 1980 futurist Toffler, also grounding on Bell's work, published his theory about three distinct waves of societies, especially describing a transition from the *industrial age* to today's prevalent *information age* [14]. These days a lot of his predictions have become reality, e.g. agricultural and production work is increasingly performed in low-wage countries whereas highly-developed countries increasingly ground their prosperity on innovation and established intellectual property. Sociologist Helmut Wilke stated that knowledge work is the key element of the morphogenesis from an industrial society towards a knowledge society. Comparable to Pfiffner and Stadelmann, he stated that knowledge work is evolving to be the standard operative mode of today's knowledge-based, smart organizations [8].

Providing essential catalysts for the progress towards a global information age *computer science* is naturally strongly involved in the area of knowledge work too. The improvements in ICT have fostered the rapid progress of globalization and in particular the fast and inexpensive provision of information. The global availability of powerful but affordable devices like personal computers or today's mobile devices, reliable and fast network capabilities like the WWW[1] and a countless variety of advanced business and end consumer software have clearly fostered this trend.

Regarding a systematic support of collaborative workers through IT, Greif and Cashman firstly defined the term of *computer supported cooperative work* (CSCW) in 1984 as an interdisciplinary research field dedicating itself to the focal question of *"how collaborative activities and their coordination can be supported by means of computer systems"* [15]. As a quite generic term it hence encompasses the way people generally collaborate in groups on the one hand and their adequate support by IT on the other hand. Initially symbolizing the first practical realization of results in the area of CSCW, the term of *groupware* was introduced describing *"computer-based systems that support groups of people engaged in a common task (or goal) and that provide an interface to a shared environment"* [16].

[1]World Wide Web

Since the term is as generically defined as CSCW there are still discussions considering the scope and application classes groupware actually encompass (cf. [17, 18]). These days groupware essentially refers to collaborative software aiming on the support of specified group by primarily free collaboration between the system's users, focusing on communication, awareness and narrow cooperation aspects. In comparison the adequate support of repeatable and standardized work had been gradually excluded to *workflow management*, mainly focusing on coordination aspects. Following a first wave of interest in workflow management starting in the mid-1980s the mentioned interdisciplinary approach of *business process management* (end-1990s) aims at the systematic and holistic support of companies' business processes and their stakeholders.

Lastly the research field of *psychology* is presented as it is also actively involved in research concerning knowledge work. In particular the research fields of *industrial and organizational psychology* as well as the related, interdisciplinary field of *cognitive science* are connected to CSCW and hence to knowledge work. Cognitive science addresses the study of human mind and its mental processes. Thereby it deals with the focal questions what cognition is, what it does and how it works and so, it naturally comprises how information is processed, represented and transformed. In this context the relations and transitions between the term of *knowledge* and the terms of *data* and *information* shall be introduced in the following in order to foster a common understanding as well as to inhibit any possible misunderstandings.

2.2 Knowledge

People often intuitively connect the terms of *data* and *information* to the term of *knowledge*. Hence the terms are colloquially incorrectly used as a substitute for each other every now and then. Based on the works of [19] and [20] a clarifying orientation it to be given illustrating the differences and relations of the terms.

2.2.1 Knowledge Foundation

Referring to the illustration in Figure 2.2, symbols can be considered as the foundation to create data. Hence a single date is created by the combination of several elementary symbols based on syntax rules. But a single date usually lacks any meaning and therefore it's not clear what it is supposed to imply. By embedding a certain date in additional data people are enabled to interpret the date in a context. So it is referenced to a real world scenario, semantics can be created and this circumstance represents the difference between data and information. At this point the term of knowledge also comes into place. In order to interpret data as information a receiver needs to have some foreknowledge, e.g. at least the words' meanings. So the value of data as information strongly depends on the receiver's individual foreknowledge and it thereby can be valued from very useless to highly precious. But knowledge is obviously not only a prerequisite, it's also a result of an information retrieval. Additionally acquired information can so enhance the existing context-related knowledge. Thereby the taking of a decision is possibly triggering and it can finally lead to an action.

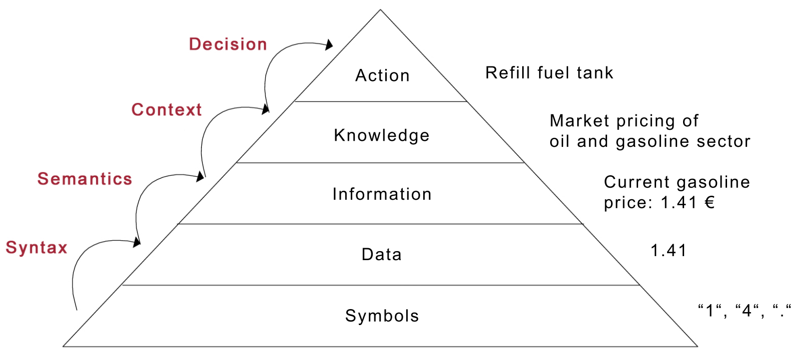

Figure 2.2: Relation of data, information and knowledge, based on [19, 21]

To illustrate the differences as well as the transitions an example shall be explained which essentials are also included in Figure 2.2.

Example:

Based on a set of single symbols and under the consideration of syntax rules a single date "1.41" is *created at first. Since this figure is quite ambiguous - it could be set in various contexts - additional data is needed to establish semantics for the figure. Thereby an information receiver is able to understand that this single date represents a gasoline price at a gas station. In the course of this he needs to have a certain degree of foreknowledge (e.g. language skills, the meaning of gasoline) on the one hand and he can use the information to enhance his existing knowledge about local gasoline prices on the other hand. Presumably he has inspected several gas stations on a quest for a cheap gas station, but gasoline has been expensive at each visited station so far. Considering the price information of this newly discovered station he decides to refill his car's fuel tank at this cheap station. Simultaneously he makes a mental note to skip future long-lasting quests.*

While the illustrative example already exposes some transitions between the different media, Davenport and Prusak provided two listings including more possible mental methods which can be used to realize the transition between data and information (adding of semantics) as well as between information and knowledge (adding of context) [20].

The following methods are supposed to create semantics on data and hence describe the *transition from data to information* in the eyes of an observer:

- *Context*: The purpose why data has been gathered is known.
- *Category*: Units of analysis and key components of the data are created.
- *Calculation*: The data is mathematically or statistically analyzed.
- *Correction*: Potential errors or inconsistencies are removed from the data.
- *Condensation*: Data is aggregated respectively summarized in a more concise form.

In addition the *transition from information to knowledge*, putting the information into context of a receiver's foreknowledge, can be ascribed by the following methods:

- *Comparison*: The received information is compared to already known situations.
- *Consequence*: Implications on decisions and actions are assessed accurately.
- *Connection*: Gained information is connected to related foreknowledge.
- *Conversation*: People's opinions and advices are taken into consideration.

Relying on the presented methods and the experiences gained from the previous example the term of knowledge is defined according to the definition in [20]. Definition 2.1 properly matches the scope of this thesis because it grounds on the established terms and insights of the last paragraphs.[2]

> **Definition 2.1** ***Knowledge*** *is a fluid mix of framed experience, values, contextual information, and expert insights that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the minds of knowers. In organizations it often becomes embedded, not only in documents or repositories, but also in organizational routines, processes, practices, and norms.*

Apart from the versatile nature of one's individual knowledge, the second part of Definition 2.1 touches the embedding as well as organizational aspects of knowledge for the first time. As soon as people work together in an organizational structure, whether it is a small group, a department or an entire company, they naturally need possibilities to express and distribute their ideas, thoughts and experiences - concisely knowledge - as a foundation for their successful collaboration. Since the thesis' focus is on the collaboration of knowledge workers, naturally including the knowledge exchange between those workers as well, the application naturally represent important subjects of interest. Therefore the relationship and transition between internal knowledge and externalized, tradable knowledge is discussed in the next section.

2.2.2 Organisational Knowledge

In 1967 epistemological scientist Polanyi published a frequently cited phrase in [25]: *"We can know more than we can tell"*. He generally shaped and discussed the distinction of the terms of *tacit* and *explicit* knowledge. According to Polanyi an individual can hold certain tacit knowledge without having the capability to explicitly express the quintessence of this knowledge. A famous example given by Polanyi, most of us can intuitively share, is the capability to hold the balance on a bicycle while riding it. This example of tacit knowledge is intertwined with personal skills and is hardly expressible until you are extensively aware of various physical principals. Hence everybody needs to gain his own experiences on a bicycle to be finally in control of the skills. In this sense explicit, sometimes called codified,

[2] An interested reader might inspect further definitions and explanations of the term knowledge in [22, 5, 23, 24].

knowledge is considered to be the opposite of tacit knowledge. It is expressible in a formal, systematic language and therefore it can be regarded as communicable knowledge (information) that can be processed by the receiver.

2.2.2.1 Knowledge Generation

Nonaka and Takeuchi drew on the subject and described transformation modes between individually tacit (the expressible shapes) and explicitly sharable knowledge in their theory of organizational knowledge creation [22]. They identified four different transformation modes, namely *socialization*, *externalization*, *internalization* and *combination* which are further discussed in the following two paragraphs (cf. Figure 2.3).

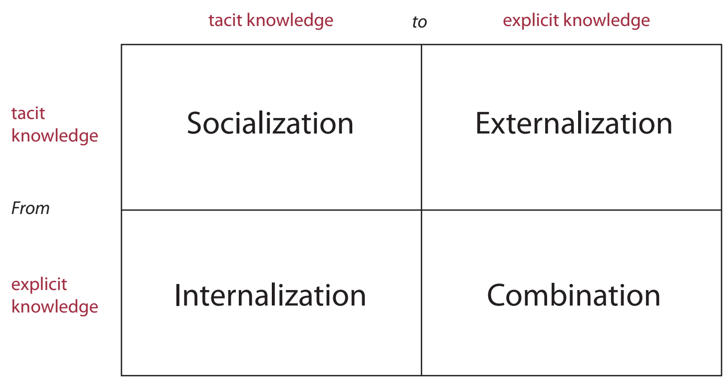

Figure 2.3: Conversion of knowledge types, according to [22]

Based on Definition 2.1 knowledge always evolves in individuals' minds and knowledge is inherently linked to its creator first. In this sense *socialization* describes the process of sharing tacit knowledge, in particular experiences, without making this knowledge explicit. Individuals can gain insights just by observing, imitation and practice, even without the usage of language, to acquire technical skills or mental models. For instance a baker apprentice maybe needs to exercise baking skills (e.g. kneading) a lot in his first years of study. In comparison, a student enrolled at an university usually acquires knowledge differently, e.g. by attending offered lectures or studying course materials. But therefore his lecturers have to perform the process of *externalization* of their individual knowledge to enable students to follow their explanations and let them broaden their horizons.

An important question of externalization is how to externalize the difficult and fuzzy shape of tacit knowledge on the one hand and a proper consideration of a target audience on the other hand. Therefore a person can avail himself of metaphors, analogies, concepts, hypotheses or models in order to establish a hopefully sequential learning process for the students. Though the quality of knowledge externalization obviously depends on multiple parameters, e.g. a person's eloquence, writing or communication skills. The process of recombination of existing, isolated information as externalized knowledge, like the previously mentioned analogies or models, is logically named *combination*. While studying the materials, students can adjust and expand their existent knowledge stock through the usage of the mentioned context creating methods (cf. Section 2.2.1). Thus an *internalization* of the communicated knowledge is taking place. Based on newly acquired insights a student can continue to deepen his understanding with gradually more profound and complex information on the subject.

So a constant repetition of the conversion modes provides the basic of an individual and organizational knowledge generation process. A steady iteration of the subsequent processes of externalization, combination, internalization and socialization can spirally advance respectively "transfer" knowledge from being individually obtained by single persons to organisationally or even inter-organisationally shared knowledge. Thus the externalization and exchange of knowledge between single knowers stepwise leads to a growth of knowledge held by everybody as well as an increase of externalized, organisationally available information.

The principals of this *knowledge creation spiral* is exposed in Figure 2.4. Nonaka and Takeuchi underlined the utilization of their theory by the provision of use cases comprising successful Japanese companies actively pursuing knowledge generation strategies as an integral part to achieve their strategic business goals [22]. Retrospectively they thereby set a foundation for the new discipline of *knowledge management*.

Based on the principals of their knowledge creation spiral they later defined knowledge management *"as the process of continuously creating new knowledge, disseminating it widely through the organization, and embodying it quickly in new products/services, technologies and*

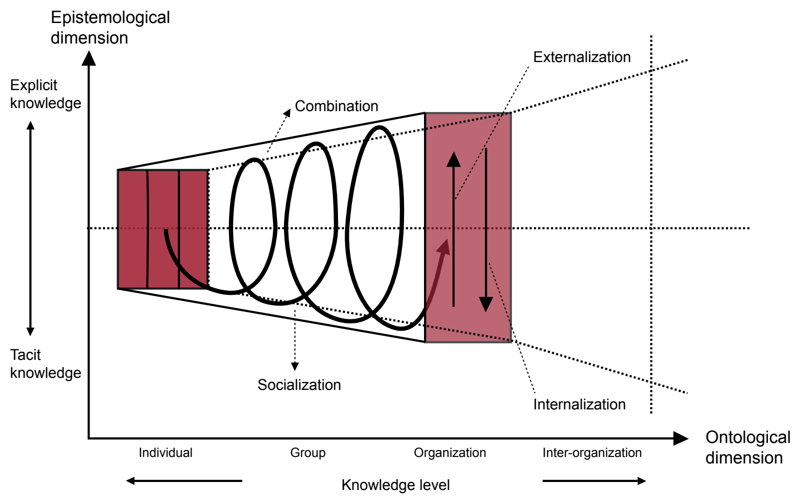

Figure 2.4: Organizational knowledge creation spiral, according to [22]

systems" [26]. To achieve the goals of knowledge management several key requirements have to be addressed considering the definition's core elements of generating, distributing and applying knowledge. As previously seen, the creation and distribution of knowledge obviously requires the externalization of knowledge into a tradable representation which thereby allows the distribution of information widely through the organization.

Additionally, distribution channels naturally have to well support those knowledge presentations and have to ensure that knowledge is properly provided to their receivers, e.g. at the right time and at the right spot. Related, information as externalized knowledge represent a certain value for their recipients depending on whether they can use it or not. Furthermore important knowledge, e.g. the knowledge about a certain technology, costly developed by a company, rationally needs to be protected. Since knowledge workers, as the name already suggests, naturally require knowledge as a focal asset for their work and their cooperation, the mentioned requirements shall be discussed in the following.

2.2.2.2 Knowledge Representation

The explicit representation of knowledge is naturally connected to carrier medium and related to the process of knowledge generation, especially externalization. Historically people had mainly encoded their knowledge analogously, primarily paper-based. The inventions of mediums like telephone, television and photography had further enriched the information supply and representation. The still ongoing transition from analogous to digital media has revolutionized the way people consume information today. Information of all types (multimedia) are now represented digitally and can be accessed in a quality and especial quantity which had not been available before. Different approaches to establish and optimize the digital representation of information have always been a strong subject of examinations and optimizations conducted by the computer science community. Digital media comprising text, pictures, sound and/or video samples are all provided in a countless variety of different content types and qualities today. In most areas a range of standard or de facto standard types have been established by either people's usage and/or norms published by industry supply. So if an information sender cannot perceive the receiver's capabilities to process a document she will most likely transform and send the document in the de facto standard content type. For instance, the file type *"pdf"* symbolizes a widely accepted de facto standard for an arbitrary exchange of text-based content [27].

2.2.2.3 Knowledge Distribution

Information as encoded knowledge is generally distributed through communication channels. The easiest channel is probably the direct, face-to-face communication between two people. More sophisticated channels like digital data transmission are often rated by their qualities, e.g. bandwidth, reliability or a noise-signal-ratio. Based on the considerable advances in information technology, like the growth of the WWW and the increasing computing power of mobile devices, more and more people are now able to perform their work practically independent of their physical workplace. The WWW can be used to publish and spread people's information via emails or other services around the globe in milliseconds. Hence this global network actually symbolizes the fastest information distribution channel that has even been accessible to mankind. However information can only be well leveraged if the receiver is capable to process the transmitted input. A simple example could be an article provided in a language the receiver does not speak at all. A knowledge provider always has to be aware of the receiver's context if she wants the receiver to understand it. For an individual on the receiving site the key question is always to obtain the personally relevant information from the supply in quantity and, even more important, quality. Especially the overwhelming information quantity is increasingly recognized as a challenging information overload [28] that crucially impedes people's productivity.

2.2.2.4 Knowledge Value and Protection

In comparison to natural resources knowledge can be shared, consumed, generally used without depleting it. But relying on the previous insights, large parts of corporate knowledge resides in the heads of the employees and if somebody resigns his knowledge will partially get lost for the company too. Thus the process of externalization and combination of knowledge is supposed to be important if a company wants to actively and sustainably secure its intellectual property. In general knowledge does not have a constant value, comparable to a natural resource the value can be estimated by demand and supply. Hence it depends on several parameters whether information is rated to be very important or totally useless for an individual or an organization. For instance, a mathematical approach will mean useless data in an individual's eyes if he is not aware of the required mathematical basics. Analogously professionals with profoundly gained domain-specific foreknowledge usually are more valuable for a company to be hired as graduates who have just left the university. In order to protect the corporate secrets, whether they reside in people's heads or in document, employees often are required to comply with corporate policies. Additionally, to secure competitive advantages companies strongly copyright intellectual properties like brands, patents and trade secrets these days.

2.3 Knowledge Work

Section 2.2 has set a preparatory work to continue with the main focus – the knowledge work. Closely connected to the increasing interest in knowledge work and knowledge workers two main and obviously intertwined questions have always been controversially discussed by professionals and scientists: *What exactly does the term of knowledge work comprise?* and *Who belongs to the set of knowledge workers?*. Thus the following sections closely inspect the subject to provide an essential understanding of the principals of knowledge work as a preparation for the ongoing sections.

2.3.1 Knowledge Work Definition

Human factor scientist Hube compared 16 different definitions of knowledge work to establish a solid foundation for his work addressing *The Description and Analysis of Knowledge Work* [24]. Therefore he selected appropriate criteria to properly assess those definitions first, allowing him a discussion about the structure and processes of knowledge work.

Hube selected and specified the following criteria:

- *Applicability of the definition for human factors science purposes in contrast to definitions for economic, sociological or business questions.*
- *Description of the process of knowledge work.*
- *Consideration of individual and subjective interpretation of knowledge work depending on assignments and involved persons.*
- *Sufficient operative distinction between knowledge work and other types of work.*

The suggested focus on human factor science yields a benefit as the science implicitly deals with the human work influenced by multiple aspects. But especially the inclusion of process perspective and a clear distinction to other work types clearly yield a valuable benefit and facilitate a common understanding of knowledge work.

Hube's evaluation resulted that only a few definitions approximately matched the specified criteria. As a consequence he refined the most promising approach of Pfiffner and Stadelmann [5] and defined knowledge work as exposed in the following Definition 2.2.

Definition 2.2 ***Knowledge work*** *is comprised of objectifying, intellectual activities, addressing novel and complex processes and (work) results, which require external means of control and a dual field of action.*

By centrally referring to *"objectifying, intellectual activities"* Definition 2.2 refers to concepts rooted in the scope of work psychology[3] which have not been introduced so far. In this context subsequent Section 2.3.1.1 provides the differences between *intellectual* and *physical work* in order to place the related term of *intellectual work* in the context of knowledge work and to emphasize the distinctive aspects.

2.3.1.1 Relation to Intellectual Work

Martin Resch categorically separated work into the performance of muscle activities, in general *manual work*, and the usage of one's mind, known as *mental work* [30]. Nevertheless work is typically performed by the use of both modes because of the simple fact that muscles cannot be induced without any previous mental activities.

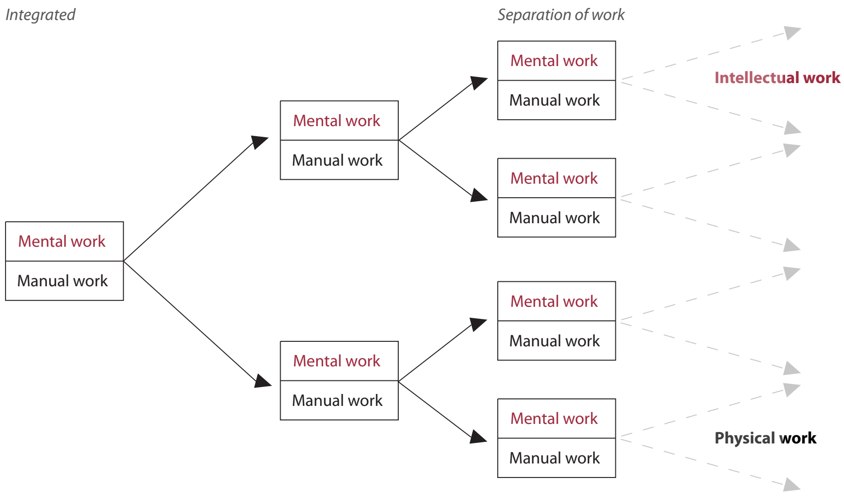

Figure 2.5: Intellectual and physical work, based on [30]

[3]A general overview about work psychology is provided by [29].

Resch further stated that the *separation of work* had led to a distinction of executive activities on the one hand and administrative, planning and managerial activities on the other hand. To describe these different types of work people often use colloquially the terms of manual and mental work too. To avoid any misunderstandings Resch introduced the more generic terms of *intellectual* and *physical work*. Though both mental and manual activities are definitely required to commit either intellectually based or physically based, executive work. But when an individual incrementally and mainly performs mental work he has performed and accomplished intellectual work. The relation between the recently mentioned terms is illustratively depicted in Figure 2.5.

As people usually perform work in a context, Pfiffner and Stadelmann introduced the notion of a *referential problem* [5]. The term symbolizes an object, an ambition or rather an objective, the *reference* of performed work, specifying the concrete scope of derived assignments. In this context they examined the possibilities to influence the reference through physical and intellectual work. Physical work instantly results in a modification of the reference since manual work *realizes* physical changes. However the result of intellectual work is generally *objectifying*. Thereby *objectifying activities* do not instantly lead to any change of a referential problem. Instead intermediate results, like plans or prototypes in the shape of document, models or objects are often stepwise created and advanced. In theory these intermediates are supposed to finally trigger succeeding activities which realize a physical change of the reference at the very end. An example would be the blueprint design of a robot developed by engineers. When the blueprint and further planning material are finally elaborated, the robot could be assembled by somebody who perform physical, realizing work. So knowledge work and intellectual work are both not realizing, instead they are both objectifying.

2.3.1.2 Novelty and Complexity

However the reference in Definition 2.2 to the *novelty and complexity* of processes and results exposes the clear distinction to the related term of intellectual work. So types of work, mainly characterized by a standardized and routine character, are thereby consequently excluded. An example to which can be referred to at this point is simple, clerical work addressing routine paper work.

The term of *novelty* refers to the *personal impression* that an assignment is crucially new in a way that personal experiences and individual foreknowledge can not be used to immediately approach a satisfying solution. Obviously somebody who has got a high degree of experience and expertise on a subject might assess an assignment to be routine work whereas the same assignment could challenge somebody else significantly. As as logical consequence, knowledge work implicitly depends on the people performing the work's activities. This important circumstance is further discussed in Section 2.4 introducing knowledge workers.

The notion of *complexity* refers to *problems or situations comprising an unmanageable set of influencing factors intertwined via dynamic correlations* [24]. So the central difference to less complex problems is made by the strong emphasis on *dynamics*: influencing factors can suddenly occur, they can change their influencing impact or they can even disappear. Furthermore the correlations between the factors also fluctuate significantly over time. Thereby unexpected, unplanned and exceptional situations can steadily occur as well as newly arising problems and ad-hoc tasks which have to be coped with.

In relation to knowledge work's novelty and complexity, Definition 2.2 refers to the term of a *dual field of action*. To better cope with novel and complex work processes an individual is supposed to use two fields of action [5, 24]. Based on the theory of action regulation (cf. [29]) Resch originally defined the two fields for the application in intellectual work: an *actual field of action*, in which work is performed in fact, and a referential field of action, in which acting on the referential problem is anticipated to define the worker's possible course of actions [30]. So, in the *referential field of action* a person merely deals theoretically with problems, he can deliberately act and test different approaches, *not causing any impact* on the referential problem! For instance alternative courses of action can be theoretically evaluated by the usage and creation of symbolical objects like temporal sketches or models. In comparison necessary instruments, actions and resources are applied in the *actual field of action* to manage the process' complexity and to finally transfer the results of the referential field of action to approach the work's objective.

To foster the reader's understanding an simple example of performed knowledge work is provided below. As an investigative reader, focus on the two fields of action (see annotations) as well as the situation's dynamics.

Example:
A new patient has just been taken to a specialised hospital for contagious diseases and he suffers, amongst other symptoms, from a high fever - he's in a severe condition overall. The responsible female senior physician receives and inspects the patient's history which includes serveral information like the progress of disease, infection possibilities as well as pre-existing conditions (actual field of action). After conscientiously studying the provided information she unfortunately realizes that the records do not fit to any disease she has got in mind. However, she is able to condense possible diseases to a manageable set of probable diseases (referential field of action). As the responsible senior physician she decides to instruct a subordinate doctor to do research about of previous cases, comparing them by similarities to find possible therapies. In the meantime she prescribes some painkillers to slightly relieve the patient's suffering. Furthermore she schedules medical examinations to gain valuable insights and to narrow down the possible diseases (actual field of action).

Integrated into the dual field of action Resch also defined seven acting phases passing through the two fields of actions and being connected by a feedback control system [30]. Generally, regulation by a feedback control system implicates the possibility to return to, or least to influence previous stages in a process. The basic idea of action regulation is that human behavior cannot be described by an unidirectional *"cause and effect"* principle. Instead people constantly compare the current state with a desired state. If there is a difference, they will act in order to hopefully achieve a desired state and subsequently perform the comparison again.

As knowledge work comprises intellectual activities Hube advanced Resch's action regulation approach for an application in the context of knowledge work [24]. This is the subject of the ensuing Section 2.3.2, dealing with knowledge work's principal time-dependent course.

2.3.2 Knowledge Work Process

Due to the dynamics in novel and complex situations and the induced need for constant adaptions, an universal, time-dependent course of knowledge work cannot be specified by detailed steps or processes [24]. However, to principally describe the process of knowledge work, Hube provided a generic knowledge work process (cf. Figure 2.6) which is generally based on Resch's seven acting phases introduced in relation to his proposed action regulation. According to Rech and Hube knowledge work, performed by a single individual, can be generally separated into different phases like orientation, planning, action, evaluation and adaption. But the phases are hardly separable and also hallmarked by fluent transitions. Phases could be multiply repeated or some might even be skipped. So the entire process is to be considered as *ideal-typical*.

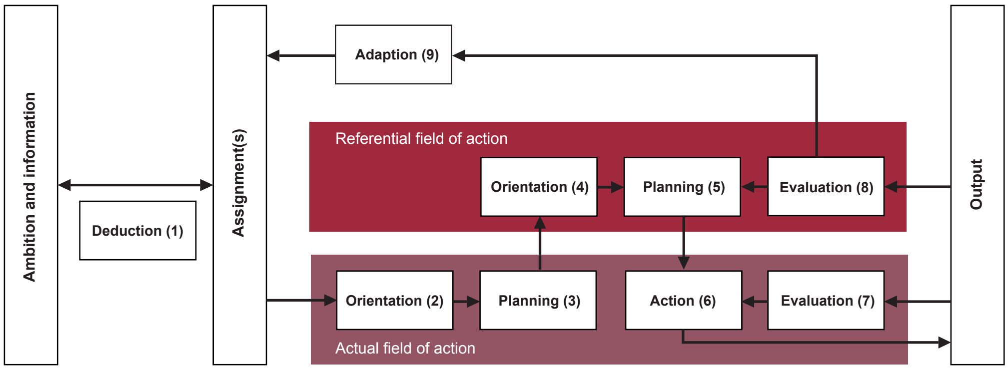

Figure 2.6: Generic knowledge work process, according to [24]

But the process yields an important benefit as it generally describes the way people perform knowledge work and how they cope with its complexity and dynamics through action regulation. The process features three interwoven feedback loops which are accounted for by the need to continuously assess the planned and finally conducted actions on their benefits and effectiveness. In addition, external influencing factors can also lead to an adaption of existing plans as well as newly gained insights may also trigger regulation and so lead to a change of the entire run of events. Thereby the regulative loops address both the knowledge work's formal quality (actual field of action) and the contentual quality and usefulness [24] (referential field of action and assignment at all).

In this sense the principal meanings of the process' phases shall be subsequently explained based on the previously introduced medical scenario. Therefore we exemplarily focus on the doctor, as a presumable knowledge worker, who was instructed to do research about comparable patient cases and possible treatments. At this point it is to be presupposed that the doctor has not performed any comparable work so far. While considering the scenario focus on phases' meanings, possible external influencing factors affecting the phases and of course the feedback control system.

1. *Deduction of assignments from ambitions and an information base*
   In this step the doctor deals with the most important question what he is actually supposed to do. Based on the instruction from the senior physician he has to deduct and specify his contribution and to anticipate the requested quality and quantity of the result. As information input he can concretely rely on a set of five probable ailments suggested by his superior as well as the patient's history and first examination results.

2. *Orientation in the actual field of action*
   He generally takes different possibilities to look at patient records into consideration. Generally he can take resources like medical books, professional publications and the WWW into consideration. More specifically, the hospital provides two data repositories: On the one hand a digital library offering well-kept patient records of the last 20 years. On the other hand a old-fashioned records library where doctors can find older paper-based records.

3. *Planning in the actual field of action*
   In this phase he checks the urgency of the assignment and schedules the execution of the task. He has to consider other assignments and appointments.

4. *Orientation in the referential field of action*
   At this point, the doctor ponders where and how he can gather the requested information respectively records. This strongly depends on experiences, individual prior knowledge and, of course, parameters like available time.

5. *Planning in the referential field of action*
   Due to time constraints and the fact that he is well familiar with the digital repository's usage he decides to query the digital records. In a first virtual attempt the doctor virtually checks whether the research can be well conducted in time. If not, the plans have to be adjusted accordingly.

6. *Action in the actual field of action*
   In this step he sequentially goes through the possible ailments and looks for similari-

ties in cases and possible therapies. As soon as he encounters an interesting case he prints relevant pages.

7. *Evaluation in the actual field of action*
   The doctor constantly checks whether intended results have already been gathered or additional queries are to be performed.

8. *Evaluation in the referential field of action*
   At this stage the doctor might need to correct his decision to merely query the digital repository. Maybe he has not found anything presentable are he has gathered information which have to validated/completed by the usage of further information resources.

9. *Adaption of an assignment*
   If the doctor was not able to find any usable information at all, or in time, he might be compelled to continue with an adjustment of the assignment.

Although the exemplary situation has not been overly complex it illustratively exposes the run of events and the output of knowledge work are naturally dependent on the person who performs the work. The person's individual expertise, experiences and preferences mainly influences the accomplishment of knowledge work since especially the factor novelty is perceived individually.

Furthermore, the course can be naturally influenced by various factors like intermediate results (e.g. unexpectedly found therapy), occurring events (e.g. emergency call), gathered information (e.g. no comparable cases) or constraints like available resources (e.g. limited time slots) as well. So the general time-dependent course of knowledge work is not ascribed to be as linear as presented above, it's rather incrementally evolving and highly dynamic. The work's intangible and dynamic nature is even increased if the doctor and his work is put into context to different work network he is certainly part of (this is discussed in Section 2.4.3).

In this context Drucker and Hube further concluded that both complexity and novelty implicates, besides the induced dynamic, knowledge workers' crucial *need for continuous learning* as well as a *high effort of communication and cooperation* [24]. Hube stated especially for potentially long-lasting processes existing knowings have to be adjusted, enhanced and revised to successfully cope with knowledge work's complexity and induced dynamics. In relation the cooperation and communication with involved process stakeholders is a natural requirement. Other knowledge workers can be considered as important data sources on the one side and the situations, knowledge work generally addresses, are mostly too complex to be coped with individually on the other side.

As a logical consequence knowledge workers and their capabilities regarding continuous learning are discussed in Section 2.4. Subsequently the important aspects of collaboration among knowledge workers are presented in Section 2.5.

2.4 Knowledge Workers

Drawing upon the previous passages this section intends to respond to the second main question of this section: *"Who belongs to the set of knowledge workers?"*. Historically, various involved research fields as well as knowledge work definitions have consequentially led to an obvious lack of an appropriate, clear distinction of knowledge workers to other types of workers.

Drucker once informally described a knowledge worker as *"an employee whose major contribution depends on his employing his knowledge rather than his muscle power and coordination, frequently contrasted with production workers who employ muscle power and coordination to operate machines"* [31]. His description implicitly provides a first distinction to a very opposite group of workers, Drucker called them *production workers*. In comparison to knowledge workers, production workers working for instance at a production line and assembling automobile components, mainly make use of their hands and perform predefined work. Related to the content of Section 2.3 they obviously perform *physical, routine work*.

The following Definition 2.3 mainly relies on Davenport's definition[4] in [7] and shows clear similarities to Drucker's statement as well. In order to establish a sound linkage to the priorly defined term of knowledge work, Davenport's proposal was slightly adapted.

[4]*Knowledge workers have high degrees of expertise, education, or experience, and the primary purpose of their jobs involves the creation, distribution or application of knowledge.*

Definition 2.3 ***Knowledge workers*** *have high degrees of expertise, education, or experience, and the primary purpose of their jobs involves the process and accomplishment of* ***knowledge work****.*

Davenport deliberately attached importance to the phrase *"primary purpose"*. Although knowledge workers primarily focus on knowledge work they can daily face a workload characterized by a span from very routine to highly challenging and complex tasks. Though this circumstance is further discussed in Section 2.4.3 dealing with knowledge workers' working principles. But as said before, the impression whether an individual rates a task to be routine or novel and challenging obviously depends on his personal degree of foreknowledge. Hence people exposing *high degrees of expertise, education and experience should usually deal better with novel and complex situations as people without corresponding foreknowledge*. This coherence rounds off Definitions 2.2 and 2.3 and establishes a strong connection between them.

As they think for a living (cf. [7]) knowledge workers also well satisfy the requirement of continuous learning and self-improvement, which is required for the accomplishment of knowledge work. Furthermore Definition 2.3 also implies that the group of knowledge workers comprises a wide range of included professions. For instance, a scientist and a practising architect could be both classified as knowledge workers, despite their different educational backgrounds, their working conditions or their performance indicators.

2.4.1 Domains and Professions

In general knowledge workers do not automatically belong to certain economic sectors, e.g. particular knowledge-intensive sectors. Instead, for instance, a manager of literally any company is supposed to perform knowledge work in order to successfully manage and improve a company's business [7]. So even traditionally industrial companies, e.g. mining or steel companies, are also reliant upon professionals like geologists, engineers, researchers, planners or procurement managers. Hence, knowledge workers can virtually be present in every domain - no matter which country, which sector or what company size.

Nonetheless there are obviously sectors proportionally employing more knowledge workers than others do. As for instance companies belonging to the ICT sector naturally rely more on continuous innovation, i.e. knowledge generation (cf. Section 2.2.2.1), than traditional mass production companies. Wilke classified various public and private organisations like high-tech companies, research institutes or commissions of inquiry to be knowledge-based, intelligent organisations in which generally much knowledge work is conducted [8]. Finally authors of various on-topic books also provide information about typical knowledge work scenarios as well as they list possible knowledge worker professions [5, 32, 33, 7, 34, 35]. Hence Table 2.1 exposes jobs explicitly mentioned in these books or which are generally supposed to fulfil the definition. Please consider this table to merely provide an informative impression of knowledge workers' professions - it cannot provide a complete set of all typical professions.

Doctor	Lawyer	Programmer	Researcher
Engineer	Teacher	Judge	Manager
Designer	Architects	Consultant	Auditor
Journalist	Business Architect	Purchaser	Software Developer
Mathematician	Statistician	Graphic Designer	Underwriter
Investigator	Prosecutor	Event Manager	Chemist
Law maker	Psychologist	Notary	Tax Adviser
Controller	Analyst	Composer	Director

Table 2.1: A set of knowledge worker professions

Conspicuously knowledge workers hold responsible positions as the exposed professions are considered as to be professionals and experts across-the-board. In this context Davenport declared *"within organizations, knowledge workers tend to be closely aligned with the organization's growth prospects. Knowledge workers in management roles come up with new strategies. Knowledge workers in R & D and engineering create new products. Knowledge workers in marketing package solutions and services that appeal well to customers. Without knowledge workers there would be no new products and services and no growth."* [7]. Unsurprisingly these workers also belong to the set of companies top earner and hence their productivity needs to be a logical and crucial concern of every company. Drawing upon this statement the economic relevance of knowledge workers is presented shortly in Section 2.4.2.

2.4.2 Economic Relevance

An exact figure of how many knowledge workers currently work in an economy is hardly possible to estimate. Statistics and related illustrations naturally lack of widely accepted definitions of knowledge workers, knowledge work and related terms. However Werner Dostal examined the *structural transformation* of the German society and the national labor market [36]. Figure 2.7 shows the results of changes in the employment structure including the diminishing importance of the agricultural, production and service sectors as well as the impressive rise of information processing jobs. Obviously workers in information processing jobs cannot be generally considered as knowledge workers. Though knowledge workers are supposed to be included as an subgroup since knowledge work comprises mentally objectifying activities requiring a high degree of information supply and exchange.

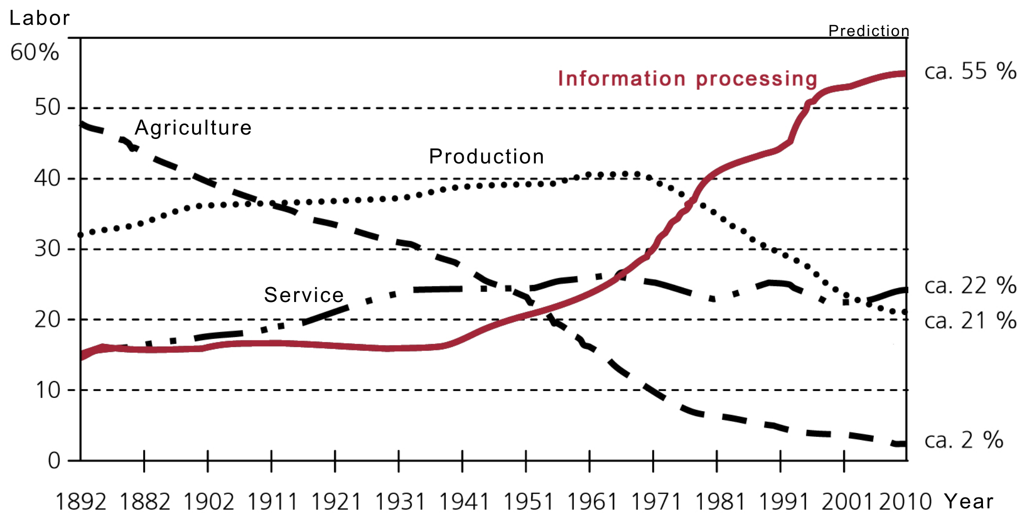

Figure 2.7: Shift towards the information age in Germany, [37]

Clearly referring to knowledge workers as defined in Definition 2.3, Dostal further examined so-called sophisticated occupations which comprise executive functions, coordination and management, qualified research, support, consulting, teaching and so forth. In summary he found and emphasized a *steady trend towards more sophisticated activities* in jobs: he estimated the proportion of people performing challenging activities *would rise up to 40%* in Germany until 2010 (in comparison, 28% in 1985 and 35% in 1995). Interestingly the ratio of medium demand profiles would remain on a level of roughly 45%, jobs dealing with mainly physically and basic activities (e.g. production workers) were supposed to be continuously less requested (2010: 16%).

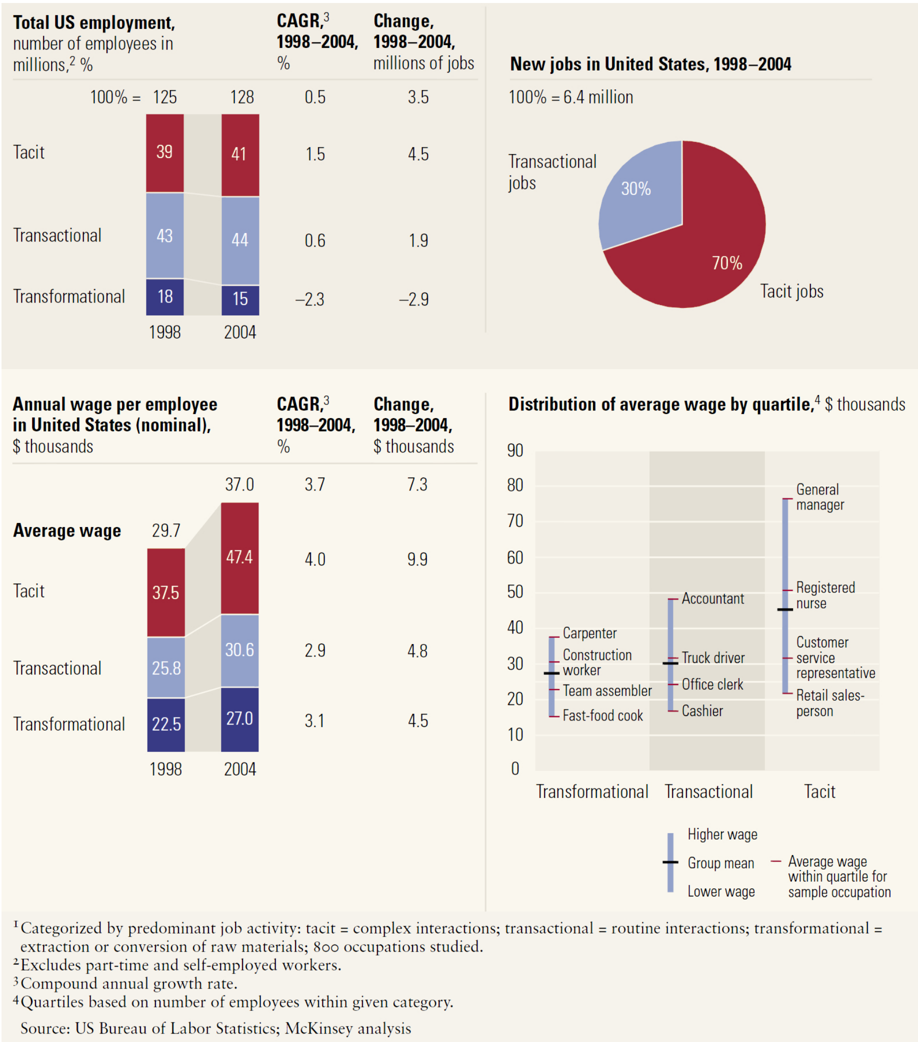

Figure 2.8: US employment and wages by job types, according to [38]

Besides the developments in Germany European Leaders published the strategic goal at the end of the European Council 2000 to become the *"most competitive and dynamic knowledge-based economy in the world"*. Although an industry-based approach does not fit to our definition, estimations can provide an impression of the relevance to a certain extent. In 2005 around 40% of the European workforce was employed in so-called *knowledge-based industries* as defined by Eurostat[5], with a job growth of roughly 24% between 1995 and 2005 [39].

For the the US labor market McKinsey also drew upon the topic and published articles about the increasing relevance of knowledge work [40, 38]. The authors defined *complex, tacit job activities* requiring a*"high level of judgement, involving ambiguity and drawing on tacit, or experiential knowledge"* - narrowly related to Definition 2.2. For their research, involving 800 different occupations, they placed every job in three distinct categories, considering predominant activities the workers perform. In comparison to tacit activities, so-called *transformational* activities refer to the extraction or conversion of raw materials (production workers) whereas *transactional* activities mainly refer to a routine and standardized workload (e.g. administrative work). As a results of the studies Figure 2.8 exposes a valuable impression about the share of knowledge workers in proportion to the US workforce as well as trends in job growth and average wage distributions.[6]

2.4.3 Working Principles

Affirmed by the economic relevance of knowledge workers for developed countries, the focal question arises again how to support these workers optimally. Knowledge workers' common working principles could offer some initial working points. But as knowledge workers do not belong to a particular profession or domain, it is challenging to expose properties which are typically shared by all knowledge workers.

Davenport, Drucker and Kogan et al emphasized that knowledge workers attach great importance to their individual autonomy [42, 6, 43]. Knowledge workers will not appreciate

[5]Eurostat's definition includes high to medium tech manufacturing and communications, financial and business services and health and education. Also included are recreational, cultural and sporting services and some travel services (sea and air).

[6]As a remark: you can find additional information and statistics as well as differences to the service economy in [5, 33, 32, 41, 8].

if they are patronized considering what and especially how they have to perform activities, e.g. in a predefined, scripted manner. *"Knowledge workers develop their own strategies for getting their work done in complex, dynamic environments in which prescribed work processes serve only as reference models"* [42]. Davenport stated accordingly that *"knowledge workers have typically thought about why and how they do their work, and may have themselves made many of the obvious improvements to it"* [7]. In order to support them individually, Davenport aimed to identify subgroups of knowledge workers on the base of various substantial dimensions like the workers' knowledge activities, costs and scale of work, working process attributes (e.g. sequential or rather parallel), business criticality and the degree of mobility [7].

He however concluded the most effective way is achieved through a separation along two important dimensions: the degree of work complexity and the level of interdependence between involved workers. According to Davenport, the level of complexity, this term has already been discussed deeply, naturally drives the degree of expertise, education and experiences knowledge workers need to successfully accomplish their work. The latter dimension exposes whether knowledge workers rather work individually or they closely collaborate with other workers. According to Davenport, this dimension is highly relevant as it ordinarily determines the degree of predictable structure and well plannable computer mediation for a particular job.

Though Davenport missed to accurately discuss the tight connection between these two dimensions. As already motivated in Section 2.3.2, Hube underlined that knowledge work addressing complex and dynamic situations virtually coerces knowledge workers to cooperate in performing and accomplishing the work [24]. The processing of novel and complex problems is usually split into manageable parts which are ideally assigned to those (available) knowledge workers who feature the needed expertise and experiences. As an example the development of a state-of-the-art robot can require experts in the areas of computer science, electrical engineering and mechanical engineering. While domain-related problems are often autonomously taken care of, the entire team of workers frequently need to synchronize the results to successfully develop the robot.

But most knowledge workers do not participate in only one group of workers addressing a certain issue. Due to their high degree of expertise and experience, knowledge workers are usually requested in multiple contexts concurrently day by day. Thereby knowledge workers often need to adopt different roles and to cooperate with distinct sets of workers context-related. Figure 2.9 exposes a certain knowledge worker (e.g. a physician) performing knowledge work as a participant in four different contexts (A-D).

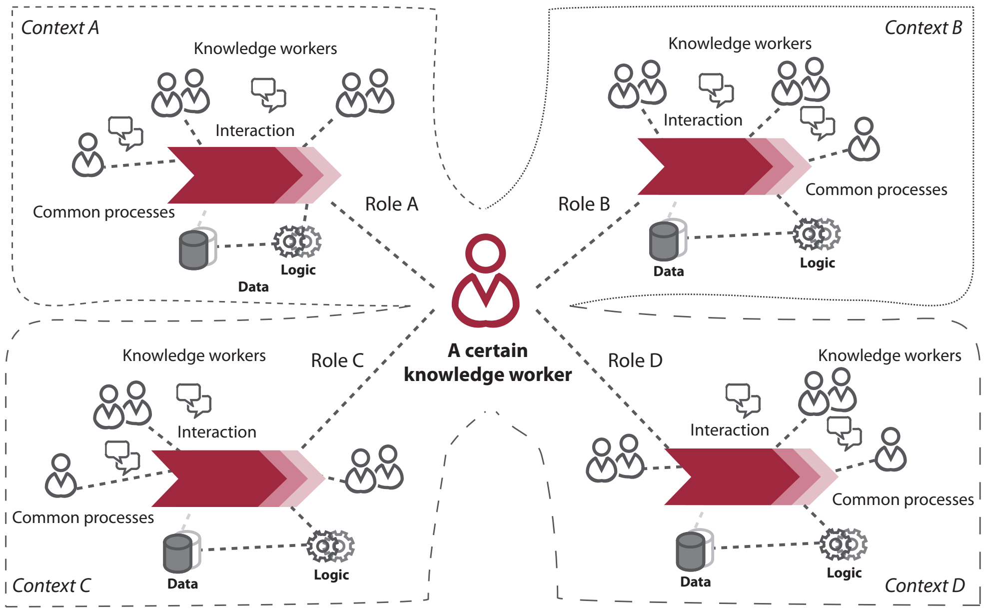

Figure 2.9: A knowledge worker obligated in multiple contexts

Thereby the main issues knowledge workers face these days is exposed. They have to manually filter, classify and manage individually context-related information to constantly project their thoughts into the corresponding context. Thus they cope with the related issue of attention fragmentation while they are trying to keep track of any progress being made in the different contexts. Although the latter problem is a principal problem of people acting in multiple contexts concurrently, the lack of information's process context increases the efforts knowledge workers have to make significantly. As a consequence an adequate support of collaborative knowledge workers is a crucial issue most of today's companies increasingly have to cope with. Hence Section 2.5 finally brings in the theoretical foundation of collaborative knowledge work.

2.5 Collaborative Knowledge Work

Drawing upon the results of the previous section, a lot of important business issues cannot be solved by a single knowledge worker in time or even at all. The processing of complex, knowledge-intensive problems and assignments are often separated into pieces which are addressed by subgroups of knowledge workers or single workers. The separation is supposed to increase effectiveness as well as efficiency in the perspective of the workers and their employers. Problems are gradually resolved by knowledge workers' teamwork and ideally a *separation of concerns* considering the knowledge workers' expert domains. In addition some separated work packages can be concurrently performed to avoid possibly unnecessary and slow sequential processing.

2.5.1 Collaborative Knowledge Work Definition

The division of labor among knowledge workers generally induces consequences which are to be discussed in the following. Therefore Definition 2.4 sets the starting point through defining collaborative knowledge work formally.

Definition 2.4 ***Collaborative knowledge work*** *(CKW) is described as* ***knowledge work*** *jointly performed by two or more* ***knowledge workers*** *in order to achieve a common business goal.*

Evaluating, CKW is logically hallmarked by two focal properties: On the one hand side it is subject to the general attributes of labor division and hence to its potential benefits and risky drawbacks. On the other hand side the inspected collaboration explicitly refers to the domain of knowledge work and the involved knowledge workers.

Definition 2.4 also established the connection to the fundamentals of BPM again. Obviously, successful collaboration among any kind of workers naturally depends on effective coordination of the activities which the involved workers perform to jointly achieve a goal. However the results of Section 2.3 clearly underlined that knowledge work processes are rather generic and crucially dependent of the involved workers' judgement and decisions.

For instance, a business process model for a knowledge work process would implicate that a process modeler is able to foresee the detailed situation and its dynamics knowledge workers will once face. In addition, the process modeler would have to be able to anticipate the involved knowledge workers' expertise and experience, their general availability as well as the activities they will perform in detail. Comparable to the support of a single knowledge worker, collaborative knowledge workers cannot be supported by detailed, predefined business process models.

2.5.2 Collaboration Example

To foster the understanding of the dynamic and unpredictable nature of CKW, an example is provided. The research project of a senior physician and a instructed doctor about possible therapies has already introduced a certain degree of collaboration (cf. Section 2.3.1). This medical example is extended as additional doctors are added to the existing scenario. For a better understanding the scenario is illustrated in Figure 2.10. In order to cope with the exceptional situation the involved doctors need to collaborate to find a therapy and to avoid a possible spread of the disease. The involved knowledge workers are tagged with numbers to be easily referenced in the following textual description.

Example:
As already mentioned the senior physician (No. 1) and a subordinate doctor (No. 2) jointly perform knowledge work in order to find a relief for a patient suffering from an unknown disease (goal). Being responsible the senior physician wants her colleague to delve deeply about similar cases and possible treatments. Based on the patient's critical condition and a possible contagiousness she decides to involve the principal consultant (No. 3) and a external specialist (No. 4). She informs both specialists about the current situation by the provision of information (e.g. patient history) and her personal judgement. She fortunately can meet the principal consultant personally, the external specialist is briefed via phone and e-mail alternatively.

Both specialists can provide her valuable information based on their experiences and they additionally promise to seek further considering possible diseases and treatments. Concurrently she constantly receives updates regarding the patient's conditions (change of state, newly occurring symptoms). By means of received input from the external specialist she contacts the instructed doctor to exclude

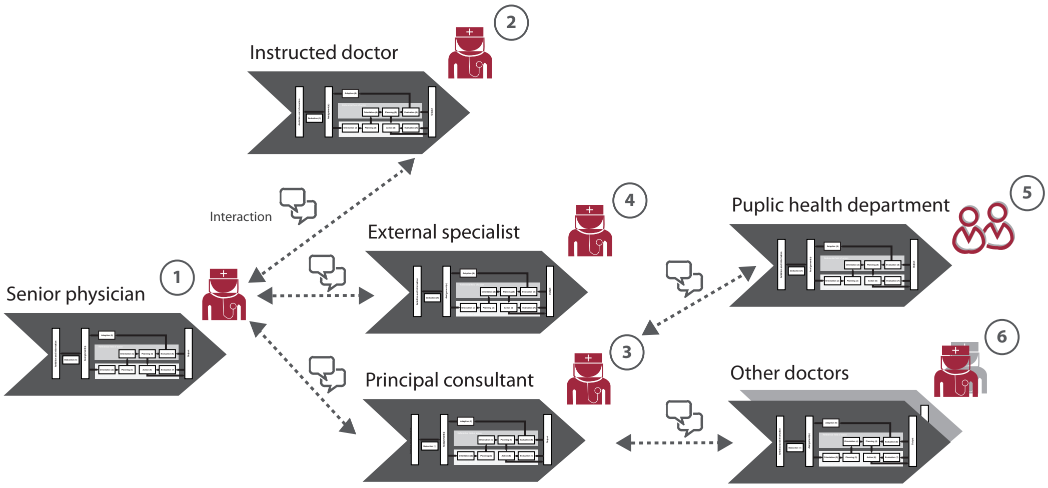

Figure 2.10: Interaction between collaborative knowledge workers

two possible diseases in his research as they are not likely anymore. As the patient's condition is aggravating again she prescribes a new dose of medicine and schedules a meeting with all involved doctors to collect and discuss available information in order to finally determine a therapy. In the meantime the principal consultant contacts the public health department (No. 5) and he initiates additional laboratory tests as he has to assume a contagious disease. As a further consequence he requests several subordinate doctors (No. 6) to join the collaborative treatment process.

Generally the depicted example is strongly characterized by *dynamics* and constant *uncertainty* mainly caused by the patient's changing medical conditions (e.g. new symptoms) as well as the implications of gained information considering the disease which the patient is suffering from. Because of this lack of reliable predictability, the course of actions is determined by decisions taken ad-hoc in response to the situation by the involved knowledge workers based on their expertise and experiences. For instance, the situation's course would be completely altered if the patient suddenly showed an allergic reaction on a prescribed medicine. This would immediately compel the senior physician to change her assignments and would initiate additional laboratory tests, further consultations and so forth. So the example is mainly supposed to demonstrate that CKW is not plannable in detail cause of *dynamics*.

Finally, the scenario also exposes several typical properties for collaboration which shall be advertised to prepare the presentation of use cases in Section 3. Labor division obviously comprises *interdependencies* and mutual *interference* between involved knowledge workers and their work. Thus successful collaboration obviously requires a way to determine who is supposed to work on which part of the entire workload and which resources are required. Therefore usually one or more involved knowledge workers have to be in charge for coordination, i.e. in the example the senior physician and later the principal as well. Generally there could occur sequential activities which are dependent on the results of the previous ones. As an example the senior physician requests the input of the research of the instructed doctor, the external specialist and the principal consultant to eventually compile the patient's therapy. But there are also *concurrency* influences resulting from the performance of parallel activities (cf. the principal consultant and senior physician both inducing laboratory tests) which might affect each other. These circumstances inherently demand an overall synchronization of work results and, as seen in the example, automatically leads to a strong need for communication between the involved knowledge workers [24].

2.6 Appraisal

Section 2 underlined that the support of collaborative knowledge workers is a versatile and challenging issue which cannot be established by existing approaches relying on predefined business processes. As a result of knowledge work's novel and complex situations, knowledge workers have to cope with a high degree of dynamics which induces a crucial need for their expertise, their experiences and their ability to constantly extend their skills. Furthermore complex situations induce a crucial need for collaboration among knowledge workers to increase effectiveness as well as efficiency. Concisely, the effective collaboration between knowledge workers is the key success factor regarding the fast achievement of a common goal – in the scenario to help the patient from his suffering. To increase the general understanding of CKW and to foster the development of an intended supportive system, three representative use cases are presented in Section 3 to discuss characteristics and distinguishing dimension CKW exposes during its performance.

3

Knowledge Work in Practice

When markets shift, technologies proliferate, competitors multiply, and products become obsolete almost overnight, successful companies are those that consistently create new knowledge, disseminate it widely throughout the organization, and quickly embody it in new technologies and products.

Ikujiro Nonaka (*1935),
professor and pioneer in knowledge management.

Section 3 draws on CKW's theoretical foundation of Section 2.5 which already introduced a medical patient treatment example for illustrative purposes. In order to further investigate the general properties of CKW, three representative use cases are presented and discussed in the following sections. The presentation of use cases underlines the practical and business relevance of the established theoretical preparatory work. After introducing the use cases, main characteristics of CKW are discussed in Section 3.2. Subsequently specific dimensions along CKW scenarios can be distinguished are introduced in Section 3.3. Finally a short appraisal is given in Section 3.4, summarizing the presentation of knowledge work performed by collaborative knowledge workers.

3.1 Use Cases

In this section the focus is put on CKW use cases which clearly comply with the requirements set in Definition 2.4. The representative character of the use cases is underscored by the various knowledge worker professions being actively involved in the use cases (cf. Section 2.4.1). Furthermore each use case represents a certain type of CKW which actually comprises a set of similar use cases. To facilitate the derivation of CKW's characteristics and dimensions, the similar use cases are shortly touched in relation to each use case as well.

3.1.1 UC1: Development Project

Use case 1 (UC1) comprises an extract of a development project for an embedded system in the automotive sector based on [44]. This use case features multidisciplinary collaboration of knowledge workers as automobiles include complex mechatronic systems these days. Hence to successfully develop an embedded system cross-domain collaboration of knowledge workers from the fields of mechanical engineering, electrical engineering and computer science is requested as a prerequisite. Common examples of such embedded systems are new features like adaptive cruise control, real-time identification of pedestrians or parking assistant systems. In order to manage development projects properly, best practices (often a generic model) are often used to systematically synchronize results and to provide an understandable overview whereby project members can orientate and perceive the current development state (macro view). A common example for such a model is exposed in Figure 3.1, the so-called V-model advices the application of development iterations and quality gates.

Starting from the entry-point the embedded system's *requirements* are first gathered to determine the goals of each development iteration. These requirements are also needed at the end of an iteration to evaluate elaborated work results. Cross-domain concepts are derived from the requirements during the phase of *system design* by decomposition of the major system requirements. Afterwards the domain-specific groups elaborate specific solutions in *engineering* phases, e.g. digital and domain-related construction

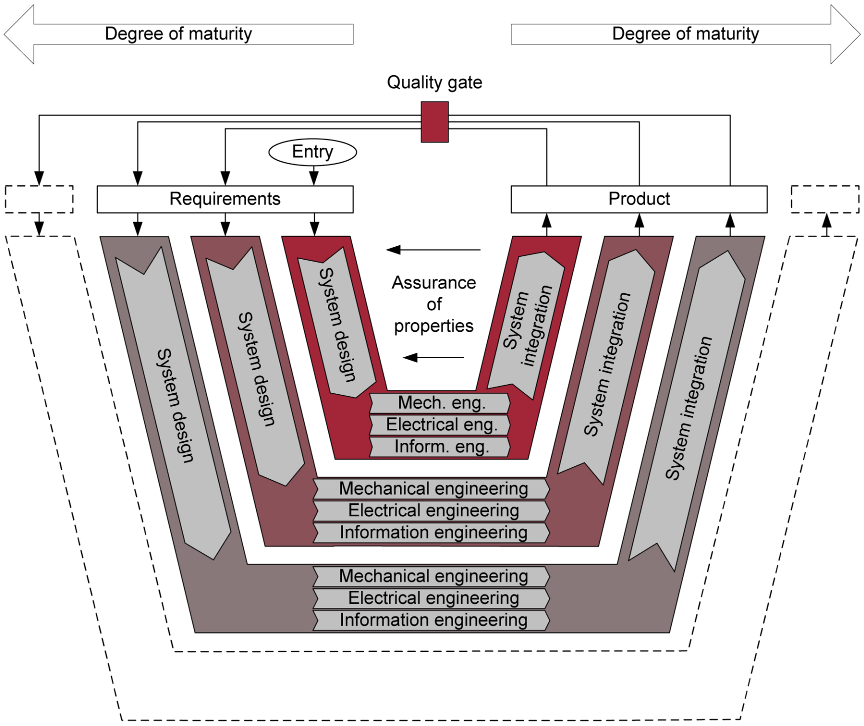

Figure 3.1: V-model macro developing process, according to [45]

plans, prototypes, specifications, test results and so forth. At this point, members of the domain-related groups can decide to use further best practices to structure their collaborative work. In the important phase of *system integration* separately developed partial components are consolidated and gradually integrated into the existing system. Thereby the resulting embedded system and the optional enhancement are compared with the previously established requirements: since complex embedded system usually need several iterations, an intermediate result (named *"product"* in Figure 3.1) has to pass an advanced quality check (*quality gate*) before another iteration is started over.

So while a best practice like the V-model is often used to ensure a general, qualitative development course, the involved knowledge workers independently perform CKW in each phase in detail (micro view). For instance, if a single distance measurement sensor is to be integrated into an adaptive cruise control system, domain-related groups of engineers (knowledge workers) have to take care of the integration into the car body (*mechanical engineering*), the establishment of physical connections (*electrical engineering*) as well as the development of control software (*information engineering*). Thereby the involved engineers, possibly physically distributed at various places, need to closely collaborate and synchronize with each other to elaborate solutions for the desired outcomes. But, as the presented phases are not as definite as the V-model might suggest, they need to be aware of the interdependencies to other workers respectively group of workers. For example, if the electrical engineers discover a severe issue, the concurrent engineering phases might have to be skipped and the preceding design phase needs to be executed again. So the detailed course of action in the development project is certainly not as linear as the V-model suggests.

This is also because electronic and information processing components are usually constructed in conjunction with mechanical components. A sequential development procedure is not desirable just because of cost and time pressures. Hence a continuous, distributed development procedure is conducted though it often includes concurrent work. But this includes sophisticated handling of highly complex interdependencies between work packages and the involved knowledge workers. Therefore intensive communication and coordination even though organisational borders is required to cope with the challenges and especially the awareness issues regarding colleague's work progress. Aspired synergistic effects obviously cannot be achieved by widely independently operating domain-specific development teams. Instead a working atmosphere characterized by common understanding, view and domain-specific terms is desired. To foster the cross-domain collaboration among the involved knowledge workers, virtual prototypes can be utilized to integrate, test and simulate important aspects. Finally, due to their importance, major automotive development projects are usually prepared and monitored conscientiously. This implies, for instance, a slated time frame, detailed cost calculations, organisation models with associated responsibilities, milestones and work packages.

3.1.1.1 Related Use Cases

Design and development projects are generally well-known examples for CKW as they are widely pervasive in domains of all stripes. In comparison to the presented automotive domain, many projects are usually undertaken in a rather domain-specific environment, e.g. a software development project or a construction project. Apart from an explicit development context, consulting projects also expose strong similarities with regard to the afore-mentioned development projects. For instance, a project managed by an IT consulting company comprising the implementation and tailoring of a new enterprise information system, is generally comparable to the presented development project as well. Furthermore research projects are also strongly related as collaborative research can address the scientific development of a solution for a selected problem through close collaboration among the involved researchers.

In general development, research and implementation projects can be considered to mainly deal with the well-organized creation of solutions (knowledge) considering a predefined problem. Usually complex situations and problems are extensively studied, analyzed and evaluated up-front to subsequently collaboratively develop a solution based on a deployed project methodology (e.g. a domain-related or corporate best practice).

3.1.2 UC2: Investigations

Another use case of CKW is represented by investigations into offenses (UC2). *"An investigation is the examination, study, tracking, and gathering of factual information that answers questions or solves problems"* [46]. An investigation usually starts shortly after a crime has been committed and investigative authorities are informed. In general, investigative work is mainly connected with the acquired information, occurring events and the reasoning and decisions of the investigators. Investigations can contain several concurrently emerging angles with dedicated investigative staff members ascertaining. While there are standardized investigative actions such as lab analyses or the securing of evidence, the investigators in charge have to individually decide for every case whether these standard procedures are needed and if yes, how they are configured and executed accordingly. Naturally investigators actively need to inspect crime scenes and to talk to witnesses. As a consequence they also depend on mobile communication and information access to instantly share and receive newly gained insights.

When organized crime has to be taken into consideration, investigations can result in transnational cooperation forcing investigative teams to interact and synchronize remotely. In comparison to the previous development project (UC1) a best practice procedure is hardly applicable. Though fluently transitive phases like securing of evidence, preliminary investigations, concrete investigations and so forth might be adequate to describe the current, but fluent state of investigation at least. Nonetheless, it can be clearly underlined that each concrete investigative case is unique in its course of action. Hence, in order to solve the crime as soon as possible (overall goal), the involved investigators need to be empowered to immediately share gained insights and derived assessments among each other. Thereby causal connections can be detected and ongoing actions can be derived and assigned accordingly. Thus the close and unimpeded collaboration between the involved investigators is a fundamental prerequisite as well as the key success factor to achieve fast and valuable investigative results.

3.1.2.1 Related Use Cases

Because of its investigative character, the work of attorneys and judges is naturally connected to the work of public investigation authorities. In addition the complexity and nuances of law necessarily requires the need for interpretation by experts who are closely familiar with the requested subjects and who are able to consider the wide range of possible criteria. Besides public authorities, companies are increasingly obliged to provide information on requests of customers, citizens, regulators or board members. So (internal) business-related investigations, like audit requests or compliance and fraud detections, also naturally belong to the pattern of investigative knowledge work.

Further extending the scope of investigations, the work of (investigative) journalists can be also factored in. They gradually gather information about a certain issue to finally compile it in order to provide the insights and clues to a broader audience. Similarly researchers can collaborate to jointly investigate a scientific issue which is characterized by a complex and challenging nature. Experiments have to be gradually conducted and the results (information) have to be interpreted and classified to derive further actions.

Evaluating investigative CKW the involved knowledge workers mainly deal with the *"exploration"* respectively *"discovery"* of knowledge in the shape of information and its interdependencies. Especially the interdependencies between pieces of information are considered to be the central valuable knowledge for involved investigators to detect important relationships and hence to foster reasoning and decisions. Hence possibilities to document and manage these relationship are natural requirements for investigative knowledge workers.

3.1.3 UC3: Complex Financial Service Request

Today a lot of business processes in the financial service sector have been increasingly standardized to assure constant quality and efficiency. However, there are still a wide range of special, often exceptional situations which have to be handled separately and individually by collaborating financial experts (UC3).

For instance, whenever customer requests do not fit predefined procedures (i.e. predefined business processes) the intervention and judgement of experienced and skilled workers is needed. Presumably, a financial service company receives a request for an unusual, complex and large-scale combination of financial products (e.g. different derivatives) from a wealthy customer. As the exceptional request cannot be handled by predefined processes, the responsible key account manager calls in available financial experts who have specialized in the involved financial products. Depending on the complexity of the combined products, further external experts and consultants might also be needed to match the customer's needs properly. To initiate the processing the manager shares additional customer-related information, the internal customer's rating and service request details with the experts. Some details are just either not available in corporate information systems or some experts do not have access to that sensitive information in general.

Based on the received input the experts individually examine possible products as well as they synchronize their results on demand. As the customer assumedly wants to receive a first offering within a week the experts have to autonomously prioritize their activities. The customer could cancel the request and contact another company if the process time was too long-lasting. Finally, the experts compiled several possible offerings and the key account manager can contact corporate legal and controlling departments. The offerings' risks and opportunities have to be evaluated as well as financial laws, tax laws and business compliance have to be complied with. In this context customer talks, but also intermediate analyses, calculations and further content have to be properly documented and archived due to accounting regulations and compliance requirements. Naturally the employees are also obliged to ensure highest degrees of privacy and reticence especially if external experts and consultants are involved.

3.1.3.1 Related Cases

Related use cases are generally found in the consideration of exceptional or rather complex business services like insurance claim handling or advanced customer services like a product change requests, loan origination, underwriting or customer onboarding [47]. Furthermore the medical collaboration example in Section 2.5.2 belongs to this type of CKW as well. These use cases have in common that they are dependent on human assessment and decisions based on knowledge workers' expertise and experiences, continuously gained information and the proper handling of unexpected events and occurring problems.

Thus the lastly presented use case mainly refers to the collaborative application of knowledge to provide a customer-oriented, complex business service. Thereby knowledge workers face the challenge to collaboratively combine existing approaches and their knowledge to provide a satisfying solution in a relatively short period of time.

3.2 Characteristics of Collaborative Knowledge Work

Ensuing the theoretical preparatory work in Section 2 and the recent introduction of use cases in Section 3.1, significant characteristics of CKW are derived and presented in the following. One main characteristic is already brought up in Section 2.5: CKW is characterized by uncertainty and dynamics due to the constantly occurring events and, in general, a wide range of possible influencing factors.

To facilitate the ongoing discussion about further characteristics, Figure 3.2 provides an abstract overview of the coherence between CKW's dynamics induced by influencing factors

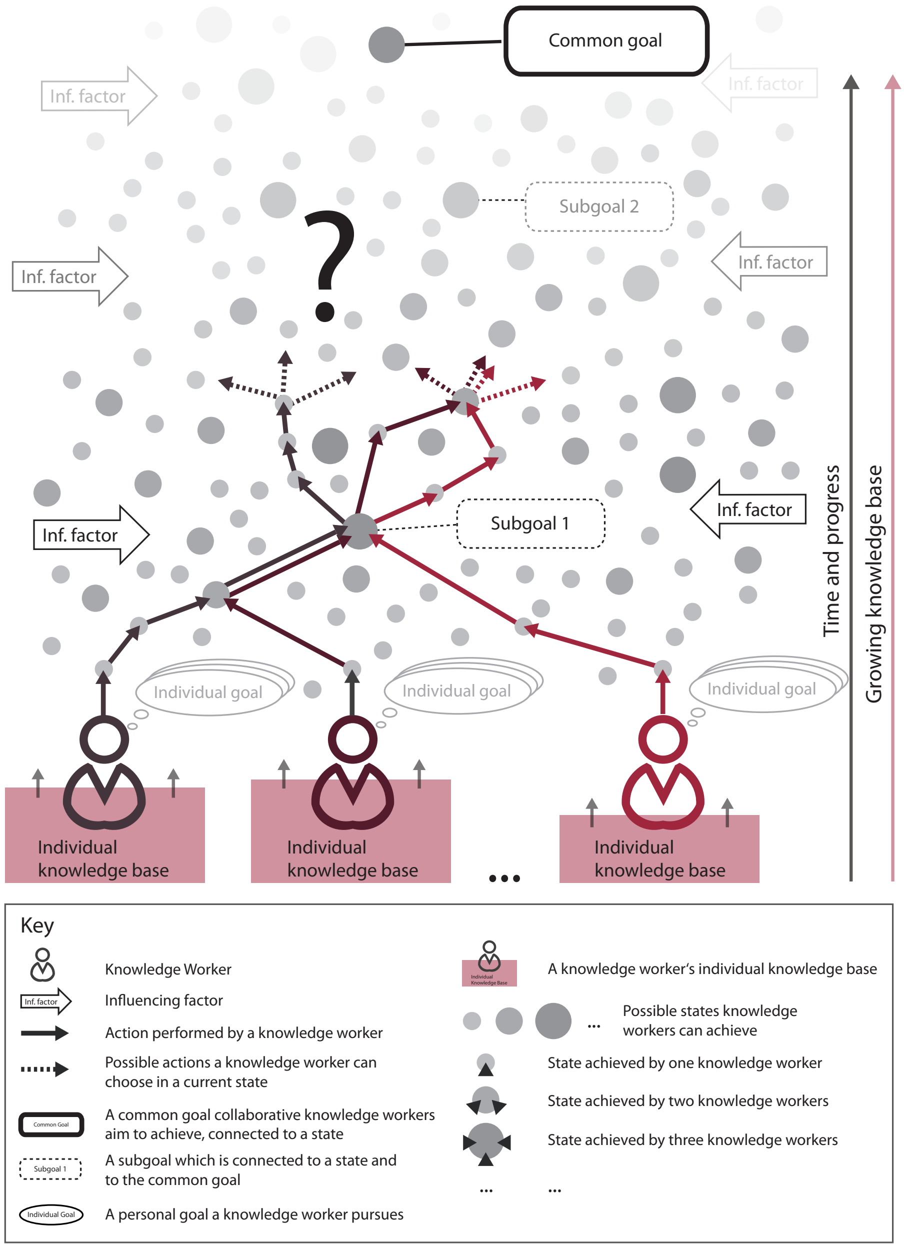

Figure 3.2: Overview and coherence of CKW characteristics

and CKW characteristics C1, C2 and C3 which are presented in the following Sections 3.2.1, 3.2.2 and 3.2.3. Thereby characteristic C1 denotes the purpose of knowledge workers' collaboration – the successful achievement of a common business goal. Subsequently characteristic C2 describes the the general emergence of CKW and C3 finally discusses the growing knowledge base of collaborative knowledge workers.

3.2.1 C1: Common Goal Orientation

The term of a *business goal* is introduced in Definition 2.4 as the objective which is why knowledge workers are expected to collaborate. Additionally, the term of a *referential problem* is referenced in Section 2.3.1.1 as the ambition why a single knowledge worker performs knowledge work. In general a shared and common goal can be considered as the *integrative factor* of knowledge workers' collaboration and hence their joint performance of knowledge work. For instance, the investigators in UC2 collaborate to solve a crime and the financial experts in UC3 aim at meeting the customer's needs. Ideally knowledge workers' individual goals are well integrated into the scope of the *common goal*. The members of the development team in UC1 likely keeps working to finally deliver a new embedded system (common goal). But at the same time knowledge workers could individually pursue their own goals or they look at the common goal from different perspectives. For instance a single developer could primarily participate in a project to extend his engineering skills and experiences.

To adequately cope with the complex and unpredictable nature of CKW, subgoals[1] are often derived to provide intermediate objectives which can be achieved in short period of time. This approach generally follows the basic principle of *divide and conquer* as comparably seen in the development process (UC1). The adherence to the V-model can enable the development team to focus on the development of a set of core features in the first iteration. Though the first subgoal *"develop core features"* could also contain further subgoals for the individual domain-specific teams as they have to conduct domain-related problem-solving concepts to successfully contribute results. While the overall goal in a CKW use case should remain rather stable, subgoals can be often created, modified or even removed (cf. Section 3.2.2). However, subgoals can also be considered as rules: as soon as a part of the entire set

[1] In the context of projects, people often refer to *"milestones"*.

of required and assigned activities has been successfully accomplished, a certain subgoal can be regarded as achieved. But as activities are sometimes hardly separable in the context of knowledge work, an alternative rule could exemplarily comprise the processing state of required documents. Subgoals always have to be considered in the context of overall goals – otherwise local optimizations for a subgoal might contrast the needs for an overall goal. In this context please consider Figure 3.2 exposing the mentioned facts as well as that collaborative knowledge workers are supposed to accomplish subgoals in order to gradually approach their common goal.

In summary, knowledge workers' goal orientation reflects a clear difference between knowledge workers and workers performing routine work. In this context Drucker stated that the crucial question in knowledge worker productivity is *"what is the task?"* in comparison to the main question for production worker productivity: *"how should the work be done?"* [6]. So based on their skills and experiences knowledge workers are in charge of deriving the "right" tasks from the common goal. Especially when many knowledge workers are part of CKW, this is not a trivial assignment. Hence common goals are important to enable knowledge workers to adapt the course of actions against frequently occurring influencing factors (cf. Section 3.2.2).

As a mindful reader you might note that goals are often connected with temporal constraints like deadlines – this topic is discussed in Section 3.3.7.

3.2.2 C2: Emergence of Work Processes

Section 3.2.1 underlines that knowledge workers are supposed to pursue a common goal they jointly aim to achieve. In doing so, they continually adapt activities to be done in order to successfully achieve their common goal. The reasons for this circumstance are a lot of unexpected situations and unplanned tasks (influencing factors) often occurring due to a lack of reliable predictability and exceptional events. For instance the sudden occurrence of relevant information (e.g. an inspector gets a clue about a suspect, UC2), abruptly limited resources (e.g. developers cannot rely on important component anymore, UC1) or arising temporal constraints (e.g. an earlier deadline for the financial experts, UC3) compel involved knowledge workers to adjust and to revise previously established plans.

As a result of uncertainty and dynamics, knowledge workers in charge usually have to focus on planning of activities being conducted any time soon (*proximity of time*). Later scheduled activities might be brought up in principal, but they are not defined in detail. CKW's dynamics just make detailed plans quickly obsolete again. By way of example UC2 (cf. Section 3.1.2) is emergent in the true sense of the word. A first hint maybe leads to a witness who can offer information about the crime's circumstances and other witnesses. Consequentially further witnesses can be questioned, yielding additional information which can exemplarily trigger laboratory tests. So the course of action is stepwise determined by the investigations' growing common knowledge base (cf. Section 3.2.3). Generally at no point of the investigations the inspectors can confidently schedule more than a few obvious activities. So continuously coordinative planning is an elementary part of those knowledge workers' daily workload.

Thus knowledge workers' agile approach of iterative planning and working results in the fact that CKW processes gradually *emerge*. For illustrative purposes this insight is integrated in Figure 3.2: knowledge workers constantly evaluate possible actions on the base of their current state and in consideration to influencing factors. At every point they have the choice between several performable actions to approach the common goal and to achieve further states. A state thereby can thereby represent, e.g., the achievement of an intermediate work result or even a common subgoal (cf. Section 3.2.1). However, due to frequently changing influencing factors as well as the need for expertise and experiences, the challenge of coordination clearly fulfills the attributes of novelty and complexity knowledge work addresses per definition. Therefore a solid knowledge base is an essential prerequisite for knowledge workers.

3.2.3 C3: Growing Knowledge Base

Unimpeded communication is logically needed to enable knowledge workers to generally exchange information in every shape, for instance their work results or some planning items. As discussed in Section 2.2.2.1, the externalization of knowledge in the shape of communicable information is crucially needed to achieve organisationally shared knowledge which can be finally considered as the solution for an addressed problem and hence as the common goal. So knowledge workers' (common) knowledge base, which includes their tacit and external knowledge, certainly plays a key role in the presented use cases.

In UC3 the financial experts rely on their knowledge to create a solid offering for their customer. Nevertheless up-to-date information about the yields of the financial products or the customer's current portfolio are certainly needed to create a sound offering. In UC3 the inspectors also leverage their skills to find new clues, i.e. information, to enhance their existing knowledge base. They constantly need to analyze the interdependencies to discover important causal relationships which might lead to a breakthrough for the investigations. The development team (UC1) face the most challenging assignment: they are supposed to elaborate the design of a new embedded system. Logically an embedded system's final construction plan eventually symbolizes the condensed, encoded shape of the involved knowledge workers' distinguished knowledge.

So, apart from the knowledge residing in knowledge workers' heads (their individual knowledge base), CKW's knowledge base usually comprises a heterogeneous set of information and records which have to be managed properly (e.g. database records, office documents, e-mails or even handwritten notes). Interestingly, for every use case the current state of progress can be roughly gathered by observing the current state of this information base (explicit knowledge base). For instance, at the beginning of the development project content like schedules, responsibilities and methodologies is stepwise created to properly organize the project. Afterwards a virtual prototype is created and then gradually enhanced further – it thereby starts to mainly represent the current development state. Principally this approach can be applied for the other use cases as well. So the progress in a use case is strongly connected to the advancement of the tacit and explicit knowledge base of the involved knowledge workers (cf. Figure 3.2).

3.3 Dimensions of Collaborative Knowledge Work

After the presentation of typical characteristics for CKW in Section 3.2, dimensions are introduced along CKW can be distinguished adequately. Naturally countless dimensions of different levels of granularity can theoretically be considered by which collaborative knowledge work scenarios could be differentiated. Hence this section intends to focus on dimensions clearly exposing significant implications for the support of collaborative knowledge workers. In combination with the common characteristics the dimensions are supposed to facilitate the intended discussion about system's requirements considering the support for collaborative knowledge workers.

3.3.1 D1: Knowledge Action Types

Generally, the use cases can be distinguished by the predominant way the involved knowledge workers deal with knowledge and information. Davenport, for instance, distinguishes between the different knowledge actions *acquisition*, *application*, *creation*, *dissemination*, *documentation* and *packaging* of knowledge [48]. Other authors provide further, different taxonomies considering knowledge workers' main knowledge activities [49, 50]. Although there are different approaches, *pragmatic analyses* of the main knowledge actions can yield benefits as the support could be accordingly and adequately adjusted. These insights are also connected to the generic knowledge work process and its steps like orientation, planning or action in Section 2.3.2. But as stated before, single steps of the knowledge work process can always be multiply repeated and even skipped if required by the knowledge worker(s).

For instance in UC2, investigators' main objective is to gain as much relevant information as possible to successfully trace back the actual incident and to reason implications for future investigative activities. In doing so inspectors have to continually analyze acquired information to discover causal relationships (other possible data sources) and to finally gain new knowledge. So the main focus of investigators is the acquisition, documentation and evaluation of information. In comparison, developers (UC1) leverage their existing skills and foreknowledge, available resources (e.g. research papers, material descriptions or an existing approach) and constructive discussions/interactions to creatively develop new (partial) solutions which, in turn, can be used again as input for another development cycle. Hence the developers naturally have their focus on the creation of ideas and their application instead of the acquisition of information and the analysis of informational relationships (however this can be also part of their work).

3.3.2 D2: Usage of Methodologies

While the course of action gradually unfolds as time goes by, the degree of adherence to a commonly accepted methodology[2] (often called best practice as well) discernibly varies in the use cases. For instance, the automotive development team (UC1) decided to apply a preselected macro structure in the shape of a V-model to organize and improve the team members' collaboration as well as to ensure a high quality development progress (quality gates). While the very details of the development project are still subject to the individuals' responsibilities and management, an overall clear procedure people can orientate by is given to ensure quality and conformance. Similarly to development projects, complex service requests could also be treated in accordance to best practices. These use cases are likely to be more structured (macro view) than the investigative UC2 or the patient treatment example introduced in Section 2.

Nonetheless procedures do not have to be explicitly illustrated, renown or even described to be successfully applied: a team can follow an implicit procedure, known and accepted by all knowledge workers, which has turned out to be successful and robust in the face of variable conditions. If there are no comparable experiences from similar situations knowledge workers could also apply an industry-specific or even a generic problem-solving approaches like *trial-and-error*. In this sense the inspectors (UC2) and the team of financial experts (UC3) rely on procedures they have learnt during their work life or education. Furthermore the introduction of a new procedure can often fail due to resistance of the affected people. In this context, knowledge workers' usual aspiration for autonomy is discussed in Section 2.4.3.

3.3.3 D3: Degree of Interdisciplinarity

The use cases additionally unveiled that CKW can vary in a range from clearly domain-specific to truly interdisciplinary scenarios. For instance, the presented UC2 addressing investigations generally involves investigators collaborating to solve a crime. While the inclusion of external specialists (e.g. for forensic medicine) is possible as well, most of

[2] A body of methods, rules, and postulates employed by a discipline: a particular procedure or set of procedures, cf. [51]

the involved knowledge workers share a common (educational) background. In contrast the development team (UC1) comprise various experts pertaining to at least three distinct domains: mechanical engineering, electrical engineering and computer science.

The collaboration of knowledge workers from different domains can lead to misunderstandings, discords (e.g. about common procedures) or even severe data inconsistencies. In this context the occurrence of synonyms and homonyms can result in high effort to synchronize contributions. For instance the word *"component"* can be easily interpreted differently by the members of the development team in UC1. Nevertheless especially interdisciplinary research is said to be highly promising for novel and complex issues and challenges. As an example, the concept of design thinking is characterized by the idea that outstanding innovation is mainly driven by intensive collaboration among professional members of interdisciplinary groups [52].

3.3.4 D4: Organisational Frames

As a general rule, CKW use cases can be distinguished by the surrounding organisational frame as well. The collaboration between knowledge workers is not compulsory bound to organisational units or static hierarchical structures. For instance, in the financial use case (UC3) the key account manager autonomously decides to involve internal or even external experts into the processing of the challenging customer request. In general knowledge workers usually collaborate either *spontaneously* (i.e. without a dedicated organisational frame) or they collaborate on the base of organisational frames like a *case* or a *project*. Albeit intermediate frames likely exist which cannot be classified uniquely, the three organisational frames are further examined as they mainly influence the coordination of collaborative knowledge workers.

For spontaneous interactions there is usually no *officially dedicated* knowledge worker in charge who orchestrates the activities of the involved workers. Instead knowledge workers sharing most experience, best skills or best job positions individually take care of coordination aspects on demand. In contrast a case usually comprises a certain knowledge worker or a small group of responsible workers, who explicitly take care of the progress of case. Referring to UC2, UC3 and the medical example in Section 2, a case usually refers to an incident, a certain person (e.g. a patient) or a special customer-related request people collaborate wherefore. In comparison, a project is undertaken *to create an unique product or service* [53]. Hence, the management of a project usually comprises conscientious preparatory work and a dedicated organisation team supervising the project and its progress. To facilitate the management of projects a wide range of standards have been generally established aiming at understandable and auditable structures as well as the assurance of quality [53].

The implications of different organisational frames for an information system dedicated to support collaborative knowledge workers, are significant. Especially coordination aspects (responsibilities, organisational models, work allocations and synchronizations) are mainly influenced by the surrounding organisational frame knowledge workers are part of during the performance of CKW. Moreover other dimensions are influenced by a deployed organisational as well. For instance, spontaneous collaboration is usually conducted for a reasonable period of time whereas projects are usually established for a longer term in comparison (dimension D7, cf. Section 3.3.7). The other way round, an organisational frame is strongly connected with the mainly performed knowledge actions: when the focus is put on the systematic creation of a solution for a well-defined problem, a project is likely conducted because a case is likely not considered as the adequate organisational frame (dimension D1, cf. Section 3.3.1).

3.3.5 D5: Degree of Spatial Proximity

Apart from preferred knowledge actions and organisational frames, collaboration between knowledge workers naturally depends on the fact whether they can properly and directly communicate with each other. Physical closeness empowers knowledge workers to directly communicate face to face whereas physically separated knowledge workers obviously have to rely on communication and collaboration tools to virtually bridge the spatial gap. Hence CKW can be distinguished by the *degree of spatial proximity* the knowledge workers expose during their collaboration.

Since the development team of the mechatronic project (UC1) comprises knowledge workers from different domains, they could struggle with physical distances as they might be allocated at different different companies and work places. Generally, a lot of software projects today comprise developers interacting remotely while being spread around the world. In comparison investigators (UC2) often have to examine crime scenes and they need to visit and question witnesses off their premises. In comparison to the development team, they are more independent of fixed workplaces and location-based assets. Thus investigators likely appreciate mobile access to latest relevant information as well as they need adequate support to communicate remotely.

In this context every fifth employed person is currently professionally mobile due to the job's demands according to [54]. Especially people with high degrees of education (knowledge workers) are more mobile than people having basic and mid-level education degrees. Moreover mobility of workers has been constantly increased by the meta-sectoral change towards service and knowledge-based economies and globalization and so, this trend is assumed to be continued [54]. Logically, the higher the degree of spatial separation and mobility the more knowledge workers obviously require computer-based support to collaborate with other knowledge workers. Finally the degree of spatial proximity is obviously connected to the dimensions D3 (cf. Section 3.3.3) and D6 (cf. Section 3.3.6).

3.3.6 D6: Number of Involved Knowledge Workers

The *number of knowledge workers* can significantly vary between the different use cases: the financial use case (UC3) probably includes less knowledge workers than the development project (UC1). Due to the emergent nature of CKW an exact number of involved knowledge workers can hardly be estimated and pre-specified. As seen in UC3, knowledge workers in charge can decide to additionally include further experts if a problem can't be solved by the existing group of knowledge workers.

However, the complexity of a problem can be generally regarded as a driver of the overall knowledge workers' headcount. Moreover the corporate importance of a project or an issue might be another reason to include many knowledge workers. But in general, the scale of involved knowledge workers naturally goes along with an increased demand for appropriate support, especially for the systematic allocation and synchronization of work (coordination). In this context, Davenport stated: *"the larger the number of people in* *a particular knowledge work job, the greater the degree of difficulty in managing, improving, or changing it."* [7].

3.3.7 D7: Rigidity of Temporal Constraints

A further dimension to distinguish between CKW use cases is offered by the consideration of time constraints being appliead to the use cases. For both the development project (UC1) as well as the financial use case (UC3), fixed deadlines can be initially connected with the use cases' goals (i.e. fixed time frames). However the development of a complex embedded system is naturally supposed to last months whereas the new financial product has to be compiled for the waiting customer in less than a week. In comparison, the investigative use case (UC2) features no fixed deadline as a solution for a crime is supposed to be found as soon as possible (relative constraint, no definite time frames).

However, investigators' time pressure to quickly solve the crime can significantly vary between different investigative cases and, in general, between CKW use cases. Hence this dimension can be leveraged to distinguish CKW use cases as well. Albeit workers might claim everything is more or less time critical these days, the saving of a patient's life is certainly more important than the compilation of a new financial product. In the context of time pressure, subgoals (characteristic C1, cf. Section 3.2.1) can be logically connected with time constraints as well. Thus the period of the collaboration's incurrence can be considered as well: a use case can emerge rather ad-hoc and fast (UC3) or involved knowledge workers have plenty of time to prepare and structurally plan the near-term, mid-term and long-term actions. Of course, this circumstance is well connected with presented dimension D4 (cf. Section 3.3.4).

3.3.8 D8: Degree of Information Interdependencies

The acquisition of information to detect causal relationships can be regarded as the main purpose of investigative activities (UC2). So closely related to dimension D1 (cf. Section 3.3.1) and characteristic C3 (cf. Section 3.2.3), CKW can also be distinguished by the complexity and importance of *information interdependencies*. Referring to UC1, an embedded system's construction plans could consist of countless interwoven components in different versions and configurations. So the more information interdependencies are in place the more crucial the need is for an adequate support to analyze and manage these relationships and interdependencies. Thereby also special requirements might have to be considered: the inspectors (UC2) need to thoroughly assess the credibility of gained information to avoid useless investigations.

Apart from internal information interdependencies, different CKW scenarios can also feature coordinative and informational interdependencies between each other. For instance in the development project (UC1,) each iteration contains three parallel phases dealing with *mechanical*, *electrical* and *informational engineering*. These phases can actually be considered and managed as sub-projects and their results finally affect the succeeding phase of *system integration*. In addition, insights and intermediates of the phases can have significant impact on the results of other phases: the identification of a major architectural issue in the electrical engineering phase could stop or even skip the work of the concurrently conducted phases. In summary, the degree of interdependencies relevantly raises the coordination complexity of CKW.

3.3.9 D9: Number of Repetitions

The *degree of the repetitive* occurrence provides a dimension that can also be leveraged to distinguish and aggregate CKW use cases. As CKW is characterized to be emergent and unique considering its activities (cf. Section 3.2.2), the dimension might sound curious at a first glance. But when targeted goals are closely considered, a repetitive occurrence of several CKW scenarios can be well observed. The development of an embedded system is likely conducted several times in a automotive company (UC1). However projects' details, like its time frame, involved workers or system's details (e.g. purpose, features), can presumably vary to a significant extent.

Apart from the same goal, the presented dimensions D1-D8 can also be utilized to determine whether CKW use case widely share common properties or whether they are generally different in consideration to the selected dimensions. The provision of a more specific support for collaborative knowledge workers obviously depends on the possibility to determine the level of similarity an ongoing collaboration shares to already finished CKW scenarios. Thereby it has to be estimated as well, which parts of past scenarios can be leveraged for the support of the ongoing collaboration.

3.4 Appraisal

The introduction of use cases and the succeeding derivation of characteristics and dimensions underlined the versatile characteristics of CKW. In Section 2.6, evaluating the theoretical aspects of knowledge work, it is emphasized that existing approaches generally do not stand up to CKW's dynamics. In particular, most process-oriented information systems cannot provide the run time flexibility knowledge workers obviously need to deal with knowledge work's complexity and dynamics.

However the thesis' results have already shown so far that CKW is not completely unstructured or arbitrary as people often claim it to be. Knowledge workers collaborate as they jointly want to achieve a common goal. Thereby goals have an integrative and motivating effect for the knowledge workers. In order to successfully achieve a goal they accordingly adapt plans, instructions and actions and they gradually extend their tacit knowledge as well as their stock of information to achieve this goal.

The presented dimensions unveiled that there are various factors and constraints which have to be considered for an supportive information system. On the one hand side, such a system will not be able to completely close the social technological gap as people usually prefer to interact face-to-face whenever they are able to (the communication is then not automatically documented context-based). On the other hand side, high degrees of spatial separation, complex information interdependencies and the repetitive execution of CKW additionally increase the need for a dedicated information system supporting collaborative knowledge workers.

Hence the established premises are used as starting points to examine the adequate support for collaborative knowledge workers.

4

Requirements for an Information System

Let us change our traditional attitude to the construction of programs.
Instead of imagining that our main task is to instruct a computer what to to,
let us concentrate rather on explaining to human beings what we want a computer to do.

Donald Knuth (*1938), distinguished writer and inventor, professor emeritus at Stanford University.

Based on the preceding theoretical and practical evaluations of CKW, requirements for a CKWS are derived in the following. Thus the section's objective is to establish and provide a set of qualitative requirements for an information system which can substantially and holistically advance knowledge workers' productivity during their emergent, context-related collaboration. To facilitate an ongoing discussion about requirements and technologies, an information system dedicated for the support of collaborative knowledge workers is hereby defined as a *collaborative knowledge work system* (CKWS).

In relation to the targeted goal of this section, Hube underlined the importance of the *availability*, the *further development* and the *communication* of *knowledge and information*. If knowledge workers are empowered to *quickly retrieve context-relevant information* as well as *experiental knowledge* in the right shape and in the right point of time, their efficiency and effectiveness can be increased significantly [24]. Hube's statements are closely in accord with the insights of Section 3, underlining the important linkage between people's common tacit and explicit knowledge base and the general progress towards the achievement of an intended goal. Hence a CKWS has to appropriately support the integration, inclusion, management and exchange of information in the current context knowledge workers collaborate in.

In order to systematically discuss the set of involved requirements, Section 4.1 introduces the principals of a holistic context-related support approach for collaborative knowledge workers. This can be considered as a basic requirement to ensure a sustainable knowledge exchange which sustainably fosters the collaboration of knowledge workers. Subsequently general system requirements like accessibility or usability are touched briefly in Section 4.2. They are generally required to ensure knowledge workers' unimpeded collaboration based on the CKWS. Finally a set of main functional requirements is presented in Section 4.3, classified in different categories and elementarily needed by knowledge workers during their performance of CKW. A short appraisal in Section 4.4 rounds off the presentation of the requirements.

4.1 Collaborative Knowledge Work Lifecycle

Knowledge workers usually collaborate in the context of a certain organisational frame to achieve a common business goal (D2 and C1, cf. Sections 3.2.1 and 3.3.4). Thus a CKWS essentially has to provide a context-based support which virtually maps the organisational frame, knowledge workers are familiar with, into the system. For instance, investigators could create a new investigative case and so they could experience accordingly tailored support for their investigative work (UC2, cf. Section 3.1.2).

To establish such a holistic supporting approach, the BPM lifecycle (cf. Figure 1.1) is leveraged as a beneficial foundation. Hence the *"collaborative knowledge work lifecycle"* (CKWL), shown in Figure 4.1, describes the holistic support of collaborative knowledge workers and is supposed to be entered in the orientation phase. The lifecycle closely draws on the generic knowledge work process (cf. Section 2.3.2) as it features *orientation*, *planning*, *execution*, *evaluation* and a kind of *"action regulation"* implemented by a feedback loop (*knowledge retrieval*). The subsequent passages are going to discuss the lifecycle's qualities and details.

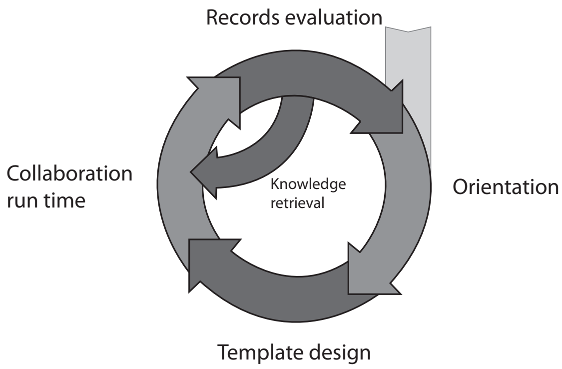

Figure 4.1: Collaborative Knowledge Work Lifecycle

4.1.1 Collaboration Orientation Phase

Similar to the design phase in the BPM lifecycle, information about how knowledge workers usually collaborate in certain contexts have to be initially gathered in the *orientation* phase. Dimension D9 (cf. Section 3.3.9) motivates that CKW sharing noticeable similarities (e.g. same business goal) can be aggregated to a *collaboration type* and hence regarded to occur multiple times. For instance, the case of fraud investigations can frequently occur in an auditing department of a large company. Hence the single case instances can share, apart from the same goal, a broad range of common properties like customarily required information in the shape of structured, semi-structured or unstructured data types, involved people and roles or compliance rules which have to be taken into account. To perform a sound clustering, the established dimensions (cf. Section 3.3) can be utilized as well to aggregate different collaboration scenarios. Moreover records of finalized collaborations (e.g. projects) can be leveraged and involved knowledge workers can be systematically interviewed to additionally gain valuable information. If neither records are available nor knowledge workers are free to be interviewed, subject-related literature and expert experiences can also be taken into consideration.

As soon as the collaboration type is successfully identified, common structures and properties can be thoroughly analyzed subsequently. While the flow of activities is the main subject of interest in the design phase of the BPM lifecycle, the orientation phase's main focus of interest is *knowledge workers' information flow*. Thereby the context-related access, the exchange of information and advancement of the common information stock are key success factors for collaborative knowledge workers. Hence in the orientation phase the content, which knowledge workers mainly deal with during a collaboration type's run of events, has to be identified. In this context, data sources and frequently used information systems need to be explicitly documented. For instance, the financial experts, collaborating to create an individual, customer-oriented offering (UC3, cf. Section 3.1.3), could be initially supported by providing access to the content they likely require during the performance of their work. Up-to-date financial data like interest rates, as well as predefined document templates which are usually required for an offering can then be easily accessed centrally.

Beside the identification of the information knowledge workers mainly deal with, knowledge workers main knowledge actions have to be considered as well (D1, cf. Section 3.3.1). Thereby the future support, provided by the CKWS for the collaborative knowledge workers, can be adjusted accordingly. Hence, to cover knowledge workers' entire information flow, knowledge workers communication habits have to be taken into account, too. Especially when knowledge workers are distributed at different places they need to communicate remotely and appropriate communication tools are required (D5, cf. Section 3.3.5). Closely connected to communication requirements, coordination aspects have to be analyzed as well. Therefore commonly used methodologies, organisation structures and frequently arising tasks can be exemplarily documented. In this context the degree of awareness information people require to initiate and perform communication and coordination is relevant, too. This circumstance as well as analytic and compliance requirements are further discussed in Section 4.3.

4.1.2 Collaboration Template Design Phase

Based on a thorough examination of collaboration types and their implicit information flows, the CKWS then offers the creation of *collaboration templates* (CT). Thereby a CT is principally comparable to a business process model supporting standardizable work accordingly. Figure 4.2a illustrates the transition from the orientation phase to the template design phase.

A certain CT is then used as a blueprint for a range of *collaboration instances* (CI) – illustrated in Figure 4.2b. Thereby a CI refers to a virtual unit representing mapped CKW: hence it can represent a single project, a single case or just a spontaneous collaboration among knowledge workers (dimension D4, cf. Section 3.3.4). But in comparison to a business process model, a CT does not prescribe neither a finite set of activities nor an ordering of those which have to performed. It is supposed to mainly provide information access, communication and coordination support embedded in an adaptable and growing framework featuring a goal for the optimal collaboration between knowledge workers in relation to their current context. For example, developers in the mechatronic development project (UC1) could instantiate a CT which was purposively created to support mechatronic development projects. So a predefined CT has to be highly adaptable and it has to be carefully designed in order to support knowledge workers without obtruding or even restraining them.

The idea of template definition naturally requires a modeling language to easily and adequately define CTs. While business process models mainly focus on the synchronized flow of activities (control flow), a CT's modeling language has to mainly focus on knowledge workers' information flow, i.e. the provision of content and adequate communication. *Especially the synchronized provision of this support for collaborative knowledge workers can be regarded as a difficult challenge due to CKW unpredictable course of action.* Therefore a kind of a state-based approach could be used to offer more synchronized support for the knowledge workers. In this context the connection to a methodology's phases (cf. the V-model in UC1, Section 3.1.1) can be logically set up. Naturally a CT's phases (i.e. states) could be regarded as encapsulated CTs which can share content and other commonalities with the parental CT. But at the same time, the subordinate CTs could offer individual support and content for knowledge workers taking care of an inferior and detailed issue. But the creation of templates, states and subordinate CTs obviously rises questions which have to be addressed by future research. For instance, the inheritance of responsibilities and access rights have to be inspected as well as the state approach automatically leads to the question whether several states can be active or only one.

Nonetheless, for the definition of CTs, different content management functionality as well as certain integrated applications for the management and editing of the involved content

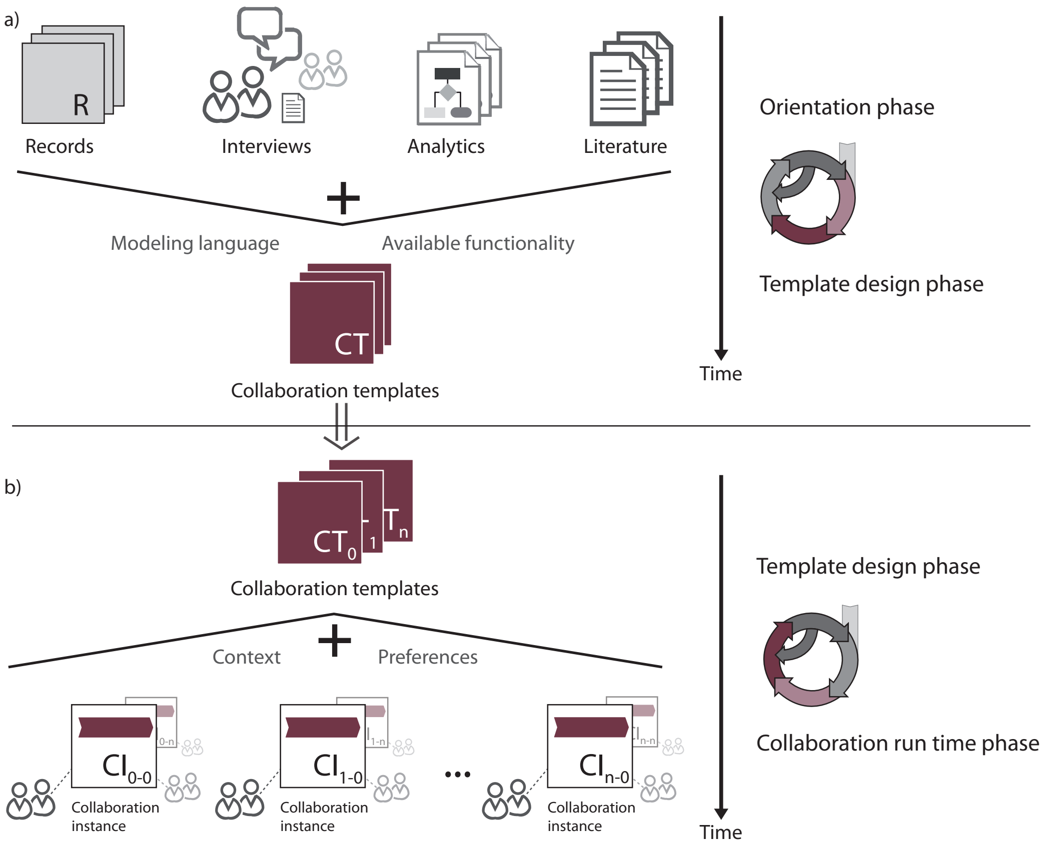

Figure 4.2: CKWL: Transitions between orientation, template design and run time phases

are generally requested as well. Regarding the access of involved content, access rights might be defined based on modeled organisational models. But organisational structures can change during the execution of a CI or knowledge workers have to be dynamically incorporated (dimension D6, cf. Section 3.3.6). So a modeling language comprising the various dimensions of CKW needs to be thoroughly addressed by future research.

4.1.3 Collaboration Run Time Phase

Based on offered CTs, knowledge workers can instantiate a CT according to their preferences and within their current context. If there is no adequately available CT, the knowledge workers can choose a rather generic template. In general, the granularity of defined CTs is an important issue: if a CT features a stringent support and implicit constraints, knowledge workers might want to choose a rather generic template features less support and a higher flexibility. But if there were only a standard template as an alternative, knowledge workers would likely complain the unpleasant gap. So CTs have to be preferably transparent and adaptive to empower knowledge workers to conduct a wide range of changes. They should be able to adjust the CT's details without being overstrained by technical details and issues.

Apart from possible granularity and flexibility issues, the knowledge workers are supposed to fully utilize the support provided by the CKWS and the defined CT to collaborate towards the achievement of their common goal. Thereby they can access integrated context-related information as well as they can add and manage information they want to share among each other. On the basis of the centrally available information, knowledge workers can communicate and coordinate using the offered communication and coordination features or additionally available, context-related integrated applications. Thereby all actions are naturally tracked by the CKWS and collaborative knowledge workers can keep track of the progress being made to achieve the common goal (based on privacy settings).

As stated the effectiveness and efficiency of knowledge workers collaboration significantly depends on the provision of experiental knowledge as well. By the usage of a CKWS, knowledge workers can access past CIs in order to retrieve important information, i.e. knowledge, which can substantially facilitate respectively speed up the achievement of the common goal. Figure 4.3 illustrates the transition and interrelation between the collaboration run time and records evaluation phase.

4.1.4 Collaboration Records Evaluation Phase

So collaboration records (CR) (i.e. finished CIs) can be considered as an important knowledge base for currently running CIs and their involved knowledge workers. They can

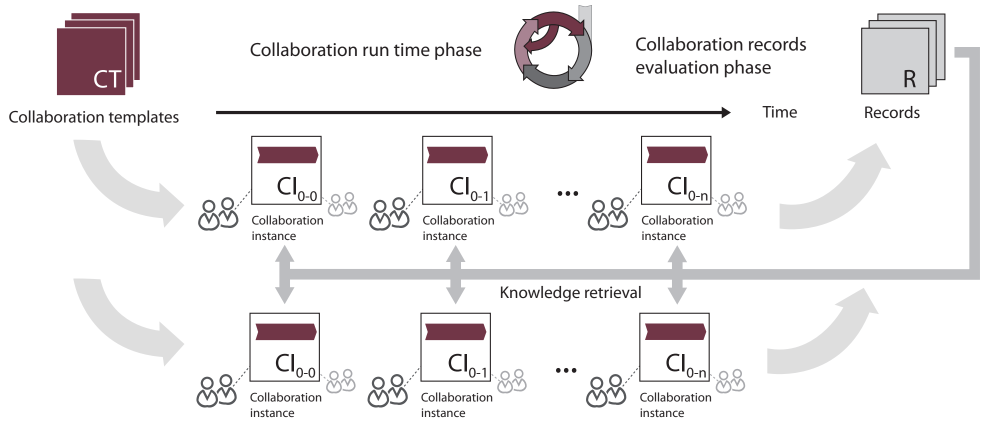

Figure 4.3: CKWL: Transition between run time and evaluation phases

look up details about past problems and they benefit from documentations of elaborated solutions. Furthermore information and their interdependencies of a running CI can be compared with information and connection available in the stock of archived CRs. Thereby beneficial information and data sources could be automatically provided by the CKWS, facilitating the progress in a CI. In addition, CRs can be used for the advancement of existing CTs as well as for the development of new, but related CTs. Regarding development projects, an elaborated solution of one project could also be the starting point for ensuing project drawing upon the achieved results and established information base. Naturally the CKWS could also check which part of a specific CT has been adapted during the run time or which part has not been used at all. Moreover the involved knowledge workers could be asked at the end of their collaboration to tag important and relevant information for future endeavors.

4.2 General Requirements of a CKWS

In order to provide a holistic and multidimensional support in accordance to the CKWL, a CKWS has to ensure several general requirements which basically allow knowledge workers to work and collaborate unopposedly. In the following, *accessibility*, *usability*, *application* *integration* and *adaptability* are touched briefly due to their relevance in relation to the collaboration lifecycle. Nonetheless there are several other (non-functional) requirements like *reliability*, *scalability* or *ease of maintenance* to which can be referred at this point.

4.2.1 GR1: System Accessibility

The use cases illustrate that collaboration among knowledge workers is not necessarily limited by corporate boundaries. In order to integrate knowledge workers as easily as possible, a CKWS has to symbolize an easy-to-reach *central point of access* for knowledge workers being involved in one or more CIs. Dimension D5 (cf. Section 3.3.5) underlines the increasing trend of professional mobility. As a result the support of mobile devices like mobile phones or tablets can be regarded as a logical challenge for a CKWS as well. The usage of these devises have been steadily grown as their capabilities are continuously improved and the bandwidth of mobile Internet access has been also advanced significantly. In relation to this spadework, a CKWS has to be easily accessible, not constrained by corporate borders or deployed software and from every place knowledge workers can potentially work from. Moreover a CKWS should also provide an access knowledge workers are widely familiar with to significantly reduce possible training periods.

4.2.2 GR2: System Usability

Related to a solution's accessibility, its *usability* naturally plays a decisive role as well. The solution's ease-of-use and ease-of-learning generally determine knowledge workers' acceptance and so finally their effectiveness and efficiency. By reason of CKW's complexity and dynamics, understandable and intuitive user interfaces providing clear structures and functionality are crucial for the success of a CKWS. Nonetheless, based on the current CT and information about knowledge workers current situation, a system needs to offer user interfaces in a contextual way. And as previously mentioned, various types of devices and their graphic rendition have to be well supported by abstracting details and restructuring layouts. In general important criteria for the system's usability are, for instance, the user interfaces' usefulness, self-descriptiveness, conformity with user expectations, fault tolerance or customizability[1].

4.2.3 GR3: Application Integration

The central, context-related provision of information implies the knowledge workers possible demand to directly manipulate information like documents or images on demand. For instance, investigators (UC2, cf. Section 3.1.2) could directly add and modify information about potential suspects in the system. The seamless integration of required applications in knowledge workers' context, i.e. a CT, increases knowledge workers productivity as they do not need to transfer information between the system and external applications anymore. Moreover a seamless working experience could be widely achieved although the integration of applications naturally means an initial and continuous effort.

4.2.4 GR4: System Adaptability

CIs can take a long time to finish and hence the support of running instance might need to be adjusted on-the-fly. Although CTs do not enforce a predefined control flow, whose adaptions are naturally tricky and challenging [56], the change of provided data and data structures can naturally result in sophisticated adaptions as well. Therefore a flexible and sophisticated conceptional model needs to be established for the definition of CTs and CIs to ensure the adaptability knowledge workers need. Furthermore a CKWS needs to ensure that future technologies and advancement of existent technologies can be well integrated. For instance, the development project (UC1, cf. Section 3.1.1) can last for months or years and it can thereby require the constant integration of new support aspects.

4.3 Specific Requirements of a CKWS

After the presentation of a holistic supporting approach as well as general requirements ensuring properties like usability and availability of a CKWS, system-specific requirements

[1] An overview of usability criteria is provided in [55].

are presented in this section. These requirements have to be fulfilled in order to successfully provide a support which allows collaborative knowledge workers to exchange and communicate information context-related. Hence the requirements directly draw upon Section 4.1 and especially refers to the CIs' run time. The specific requirements are classified into six categories, namely *content support* (SR1), *coordination support* (SR2), *communication support* (SR3), *awareness support* (SR4), *analytics support* (SR5) and *compliance support* (SR6) (cf. Sections 4.3.1-4.3.6).

Logically the system's main priority is the provision of context-related information as well as possibilities to add, edit, share and delete that information. Hence CKWS's requirements regarding the availability, integration, inclusion and management of *content* has to be addressed. The term content thereby refers to *structured and unstructured information that is provided for an audience (knowledge workers) within a specific context*. Drawing upon the CKW characteristics C1 and C2 (cf. Section 3.2.1 and 3.2.2), knowledge workers do also require adequate support considering *communication* and *coordination*. Communication channels and standards have to be integrated to allow knowledge workers to collaborate on the base of the provided content. Furthermore knowledge workers should be able to define goals and subgoals or to assign best practice procedures where the workers can orientate by. Besides they need support to cope with the challenge to continuously manage work interdependencies between knowledge workers and their performed work.

To ensure content, communication and coordination support for collaborative knowledge workers, a system has to additionally provide *awareness*, *compliance* and *analytic* support. Awareness information is crucially needed for smooth communication and coordination. For instance, information about the knowledge workers themselves as well as their capabilities is beneficial for the coordination of work. The consideration of compliance demands need to be ensured as it refers to issues like security, privacy or business policies. Usually the adherence of necessary compliance regulations limits the people's opportunities of actions, thereby it naturally influences all parts of collaborative knowledge work. Analytics are needed to support knowledge workers with the possibility to filter information and to analyze information relationships to finally gain additionally relevant information.

4.3.1 SR1: Content Support

Due to the fact that a shared context-related knowledge base is one of the most crucial requirements for collaborative knowledge workers this section deals with the requirements regarding content. Generally content can be provided in different availability modes: first of all there can be content which is supposed to be accessible for all knowledge workers. Furthermore content can be limited to a set of CTs or a single CT. If content is limited to a CT, all derived CIs will be able to access this content. For example, information generally concerning investigations conducted by a public authority (UC2) can be offered for all derived CI initially. Lastly there is content only available in a specific CI. Thus knowledge workers who are involved in a certain CI can access globally available content as well as the content of the parental CT and the specific CI-related information. This set of facts is depicted in Figure 4.4.

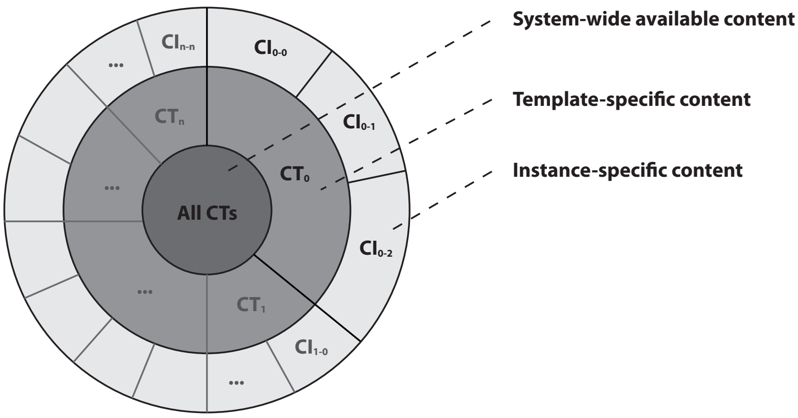

Figure 4.4: Content availability in a CKWS

Naturally the availability of content is supposed to be limited by the knowledge workers' roles and connected access rights. Overall, a CKWS needs to enable knowledge workers to add content to a CI and to easily specify the audience of the content. As a consequence a knowledge worker needs to be able to add and define content as private to preserve information for himself in the right context. While content can be manually added or created by knowledge workers, a lot of information can be obviously encapsulated in systems and application. Hence the proper integration plays a decisive role - this is deepened in the following Section 4.3.1.1.

4.3.1.1 Content Integration

Based on thorough analyses in the CKWL's observation phase, possibly required content is identified which is actually governed and updated in external systems (e.g. ERP or CRM systems). As an example, collaborative physicians dealing with a patient's complex treatment obviously require access to the patient's history, files and further content like insurance details. But if a large quantity of content is integrated for a CT, different content types and content structures have to be analyzed and consolidated well. Concretely, different data schemes, data semantics (homonyms and synonyms) and redundancy have to be considered and brought together by a powerful middleware concept [57]. Furthermore various interdependencies between data elements have to be taken into account and several parameters (e.g. transparent content editing, access rights) need to be configured carefully. Furthermore the presentation of the integrated content to the knowledge workers has to be specified as well. Obviously *the integration of content and its data sources is one of the main challenging tasks concerning the targeted establishment of a CKWS*.

While there is specific content which can be integrated into a CT a priori, the connection to data sources might also be promising if the concrete demand cannot be foreseen in detail. For instance, if a digital patient case repository is integrated into a CKWS, doctors can look up and add possible results directly to the CI. Thus a CKWS needs to ensure the connection to, or even the integration of, as many corporate data sources as possible in advance to enable knowledge workers to dynamically assign corporate content to a CI. In this context, data can be specified as mandatory for a CT in order to dynamically load external data during its instantiation. For instance, a customer identification number can presumably be considered as necessary to start a new *"complex financial service"*-CI for the financial experts (UC3). As this customer-related information can be subject to constant change, a CKWS automatically gathers and assigns up-to-date information to the CI. However the knowledge workers need to have the choice whether content is continuously updated or whether content can remain stable after its initial gathering.

Of course updates for information hosted in external systems and integrated into the system can be propagated to the CKWS and the involved knowledge workers. But updates generally need to be reasonable and traceable for the involved knowledge workers by elaborated concepts (e.g. by version control). Otherwise inconsistencies could obviously occur as integrated information like documents can have interdependencies to other content in a CI. Alternatively a knowledge worker might require content to be integrated into a CI from external systems at the very beginning and to remain stable. Thus that content can be considered as *detached* from its original source - comparable to information which is gradually added manually by users.

Knowledge workers generally need functionality to dynamically add content on demand in order to share those with the involved workers during a CI's run time. For instance, financial experts can receive a requested customer loan assessment document they naturally want to incorporate into the current CI (UC3). Therefore a CKWS has to provide sophisticated functionality to cope with a wide range of possible content types and structures. Knowledge workers have to be enabled to dynamically add content of any kind, e.g. paper-based documents or multimedia files. Furthermore general standards for the provision of content also have to be supported to allow knowledge workers to dynamically add entire data sources like RSS feeds or web services.

4.3.1.2 Content Management

The knowledge workers' collaboration based on a CI implies their need for adequate *content management* support considering the integrated content. *Therefore a CKWS has to offer well usable content management functionality to dynamically find, add, edit, share and remove a wide range of content of different content types.* Through the mentioned possibility to establish a retrieval connection to corporate data sources, knowledge workers can dynamically search and add information on demand. In addition sophisticated editors have to be provided to allow knowledge workers to instantly edit included content or to (collaboratively) create new content in the corresponding context on the system. Collaborative editors could enable knowledge workers to concurrently edit content context-related and integrated in the CKWS.

The management of content also includes the creation of adequate structures and classifications to foster the productivity of knowledge workers (dimension D8, Section 3.3.8). As knowledge workers are supposed to change content on demand, a history (i.e. a time line) about previous changes and explicit version control concepts are required. Moreover if the workers intended goal has been finally achieved successfully, the CI's content has to be archived adequately. In this context a lot of compliance aspects have to be properly ensured, e.g. feasible compression techniques or encryption. Furthermore a part of the content might have to be deleted due to compliance regulations like data privacy (cf. SR6, Section 4.3.6).

4.3.1.3 Knowledge Management

Intertwined with the regarded content management requirements, *knowledge management* functionality need to take care of the context-related provision of beneficial experiential or expertise information on the one hand side and of the continuous gathering of CT-specific knowledge to support related or future collaborations with even more experiential information on the other hand side. In this context the connection to external knowledge repositories providing experiential knowledge needs to be established. Beside external repositories, "local" knowledge repositories like a dictionary, a thesaurus or a wiki (cf. Section 5.1.1.1) can be deployed for a set of CT or a single CT. Thus knowledge workers, collaborating on the base of derived CIs, can use local knowledge repositories to look up, define and change ambivalent terms and topics (dimension D3, cf. Section 3.3.3). Moreover they can save best practices and gained experiential knowledge for ongoing collaborations.

As an example, the inclusion of an open dictionary as well as a best practice repository for interdisciplinary development projects (i.e. different CTs) in a fictive automotive company can facilitate the work of the involved developers significantly. Thereby ambiguous terms are clarified by the knowledge workers for a sound and common usage. Moreover solutions for intermediate problems can be directly stored and published in order to facilitate the work of other knowledge workers. Furthermore, the investigative UC2 and dimension D8 (cf. Sections 3.1.2 and 3.3.8) underline knowledge workers' need to create and maintain information relationships. These relationships are substantially important for investigators and represent valuable information, i.e. knowledge. Therefore a CKWS needs to provide possibilities to manage such relationships and also to detect causal interdependencies. While the management of information relationships is naturally intertwined with the previously introduced requirements regarding content management, the detection of relationships is to be further discussed in Section 4.3.5 dealing with analytic features.

Apart from dedicated knowledge repositories, the CKWS itself can be considered as a crucial part of a corporate knowledge management strategy and implementation. The CKWS is directly aligned with Nonakas and Takeuchis knowledge creation spiral (cf. Section 2.2.2.1). As knowledge workers interact context-related on the CKWS, it can well capture the continuous adaptions made by knowledge workers to achieve a common goal. According to CKWL, knowledge workers can later access provided CRs and leverage results, procedures and information about involved workers from past instances (cf. Section 4.1.4).

4.3.2 SR2: Coordination Support

CKW characteristics C1 and C2 (cf. Sections 3.2.1 and 3.2.2) conveys that CKW processes cannot be foreseen in detail, instead they are highly dynamic and knowledge workers themselves iteratively determine future actions. In order to cope with novel, complex and hence demanding problems knowledge workers need to collaborate and, hence, they also need to coordinate each other. So *coordination* is an integral part of work knowledge workers have to perform while collaborating. Logically a CKWS has to provide a sophisticated coordination support to reduce knowledge workers' efforts.

The coordination between knowledge workers is obviously closely connected with communication requirements as there is no enforced script or business process model which knowledge workers generally have to follow. Instead intermediate assignments have to be communicated, explained and detailed. So a coordination approach is needed which enables knowledge workers to coordinate each other during run time in an agile way. But nevertheless, the orientation towards goals has to be supported as well as the consideration of best practices (methodologies). In summary near-term, mid-term and long-term coordination support has to be provided as Figure 4.5 illustrates.

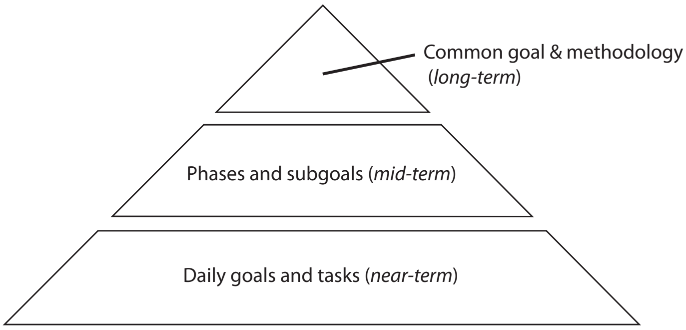

Figure 4.5: Knowledge workers' coordination pyramid

Knowledge workers generally perform activities to achieve a common goal, but their activities are not independent from each other. Instead there are dependencies being used by the knowledge workers to achieve desired results and to prevent undesired effects. Those purposeful, mutual dependencies between the activities are called *interdependencies*. So general coordination concepts can be principally utilized although the coordination between knowledge workers is agile and dynamic. Malone and Crowston presented three fundamental types of activity interdependencies being highly relevant for coordination and hence for collaborative knowledge workers as well [58]:

- *Management of producer/consumer dependencies*: consideration of two activities whereby the second activity depends on the input of the first activity. Thereby the first activity is seen as producer and the latter as consumer.

- *Management of simultaneity constraints*: consideration of activities which have to be accomplished concurrently due to constraints. For instance the synchronization of work results usually requires the participation of knowledge workers at one time (e.g. a meeting).

- *Management of shared resources*: different activities require selected resources which are merely available to a certain extent. The right allocation of resources (e.g. content and people) thereby determines about the degree of knowledge workers' productivity.

Logically the concepts of coordination are closely connected with all requirements in this section. As CKW gradually unfolds due to the set of influencing aspects and events, knowledge workers have to continuously define and adjust interdependencies of the presented types to finally achieve their common goal. Therefore a CKWS has to provide coordination features to manage these interdependencies, strongly intertwined with other aspects like communication and awareness information supply. Thus Section 4.3.2.1 introduces the definition of goals, Section 4.3.2.2 subsequently addresses the usage of methodologies and Section 4.3.2.3 lastly discusses ways of agile coordination knowledge workers require. Finally, Section 4.3.2.4 motivates knowledge workers need to initiate standardized processes on demand.

4.3.2.1 Goal Definition

CKW characteristic C1 underlined that goals generally play an important role for successful coordination among knowledge workers. Hence the question has to be entered into: *"how to set the right goal(s)?"*. Depending on the right, clear definition of a common goal and derived subgoals knowledge workers either work effectively or rather ineffectively. In comparison, if goals are ambiguously collaboration among knowledge workers will likely fail in achieving a common goal. Apart from a common goal, responsible knowledge workers make use of subgoals to further structure the work and provide shortly achievable objectives to foster the motivation of involved knowledge workers. Hence a CKWS has to actively bolster responsible knowledge workers in the definition of proper goals (common goal as well as subgoals) for a CT and during the CIs run time. Therefore the concept of *"S.M.A.R.T."* goals can be exemplarily used as a referential method to define understandable and meaningful goals [59]:

- *Specific*: goals need to be clearly defined in a specific manner to clarify the question word "why" and to touch on "what" in an abstract way.
- *Measurable*: people should be able to assess the current state of affairs and it needs to be clear when the goal has been reached.
- *Assignable*: the definition of goals has to address who is responsible and also likely involved during knowledge workers' collaboration.

- *Realistic*: a definition of a goal has to be necessarily realistic to ensure that people are willing to work towards the achievement of a goal.
- *Time related*: it is necessary to ground a goal with a time frame. The existence of a deadline helps the involved persons to align their efforts on completion before the intended due date.

Of course information technologies cannot set goals on their own, but if the CKWS brought up the mentioned goal quality aspects and a solid base of information (e.g. information of previous projects, available resources, etc.) responsible knowledge worker can utilize the support and define goals for CTs and CIs more successfully.

4.3.2.2 Methodologies

As the importance of methodologies for collaborative knowledge workers is motivated in dimension D2 (cf. Section 3.3.2), a CKWS should support the provision (of predefined) and the application of methodologies by knowledge workers. A certain procedure might be enforced by the company as best practices, optimized and enhanced for years and people share common and deep experiences with it. The principals of a methodology can often be visually presented by subject-related process models, e.g. a V-model or further development methods [60]. Thereby a solution should provide the graphical creation, implementation and modification of the offered and applicable methodologies. However a methodology is not a strict business process: the CKWS needs to provide enough flexibility to allow knowledge workers to change and alter the suggested way whenever they need to.

In UC1 (cf. Section 3.1.1) for example, knowledge workers who are responsible for single domain-specific phases in the development project could decide to apply a domain-related procedure to their collaboration. Thereby the CKWS has to ensure the support of encapsulated applications of methodologies respectively the encapsulation of CTs. As a result, the definition and maintenance of methodology is tightly connected to flexibility and support of CTs. The usage of methodologies can mainly determine the principal course of events since main parts of the derivation of what has to be done are influenced. So apart from the structuring a CT, e.g. by different, iterative phases like planning, action and synchronization, the application of a methodology usually implicates the creation of organizational structures, like roles, teams or an organizational hierarchy (dimension D4, cf. Section 3.3.4).

4.3.2.3 Agile Coordination

Characteristic C2 and the dimensions D6 and D7 (cf. Section 3.2.2, 3.3.6 and 3.3.7) motivate the need for a continuous and agile coordination approach for CKW. A CKWS has to provide advanced coordination functionality in order to empower knowledge workers in charge to continuously manage all relevant coordination aspects. Based on the coordination theory as well as BPM fundamentals, knowledge workers need the possibility to assign work to responsible persons on the one hand side and to manage the mentioned interdependencies between knowledge workers on the other hand side. As knowledge workers work quite autonomically, the assignment of work packages could also be conducted via advertising a set of tasks and people can voluntarily accept the "challenge". Obviously such an approach contrasts the classical, imperative task assignment strategies of BPM. In general the workers often interpret tasks like goals and they individually decide how to perform the work in order to achieve the requested work result. Thereby work assignments should be rather appropriately ascribed as individual goals. Finally for each activity, related resources like certain content should be assignable to ease the initial effort for knowledge workers and additionally provide them relevant information input.

The continuous creation and maintenance of temporal and resource-based interdependencies can be considered as the main challenge for responsible knowledge workers. Situation-related knowledge workers might decide to impose rigid temporal dependencies to the collaboration of instructed workers. Regularly the knowledge workers regard the proximity of time and focus on assignments and goals which shall be finished and achieved any time soon. Therefore a lot of producer/consumer relations as well as synchronization events (e.g. meetings) might be created to structure the collaboration among the workers. This approach could be successful because of the potential complexity of the work, the involved workers might feel to be eased from additional coordination effort – they can so focus on their actual work. On the other hand this approach could also fail due to possible potential of over-regulation and an eventual loss of motivation – people might feel constrained in their ability to act themselves, using their creativity and their rehearsed procedures. In this case, the assignment of coarse-grained work package to several persons allowing them to coordinate each other themselves by interactions and communication might be more promising [61].

So a CKWS is supposed to provide possibilities to create and adjust temporal coordinative flows as well as to allocate resources at any time although they are supposed to be not as rigid as known from the automation of business processes. Crucially, to successfully assign work and related content to knowledge workers, responsible persons need to be aware of relevant information about their coworkers. For instance, information about their degrees of expertise and experiences on specific subjects, information about whether these people are currently available or general information about their progress regarding a certain task can be obviously regarded as highly valuable. These requirements refer to the integral term of *awareness* which is discussed in Section 4.3.4.

4.3.2.4 Processes Initiations

Considering the use cases (cf. Section 3.1) knowledge workers frequently initiate associated business processes in order to delegate work and to be able to process the results later. Thereby a CI can be considered as a *conjunctive point* initiating processes as well as receiving and processing results of standardized business processes. Regarding investigations (UC2), examples are laboratory analyses or the preservation of evidence. Thus a CKWS has to ensure the proper integration of enactment possibilities into CTs in order to allow knowledge workers to invoke required processes in the context of a specific CI.

In addition, knowledge workers can also require the current execution state of initiated processes as well as different variants of predefined processes based on the current state respectively situation. Thereby various implementation details have to be clarified: for instance who is allowed to trace the execution state and who is supposed to receive the result(s) of a started process. Moreover the provision of executable processes requires a high degree of context sensitivity to empower knowledge workers to trigger the right processes at the right time. Apart from the invocation of external processes, a CKWS needs to implement a wide range of internal processes, too. Based on the variety of required functionalities in the area of content (cf. Section 4.3.1) and communication (cf. Section

4.3.3), the CKWS obviously needs flexible, implemented business processes to orchestrate these functions.

4.3.3 SR3: Communication Support

The support of advanced and unimpeded *communication* among knowledge workers through rich and powerful communication channels integrated in the CKWS must be considered as a crucial requirement with a high priority. *Especially the coordination of, and among knowledge workers heavily relies on appropriate communication between the workers* (cf. Section 4.3.2 and characteristic C2, cf. Section 3.2.2). For instance, common goals, incentives or required information input have to be mediated to assure successful collaboration. When knowledge workers are spatially distributed they require and rely on an unified communication concept to bridge the spatial gap (dimension D5, cf. Section 3.3.5). Thereby communication abstractly represents a connection link between the underlying layer of content and the structuring concept of coordination.

Integrated communication on the CKWS can yield several benefits as knowledge workers then can communicate in the context of a particular subject (e.g. a document belonging to a CI they are integrated in). Further communication can be documented and indexed to be resumed or to be leveraged in other contexts later on. As an example, communication via today's predominant electronic message service e-mail often causes the issue that communication is mainly detached from its context.

To provide rich communication channels a CKWS needs to cover a wide range of today's accustomed, important shapes of communication: knowledge workers need to be enabled to communicate text-based as well as by audio and video. Multimedia communication also comprises different modes like the differentiation between one-on-one conversations or conversations involving many participants (e.g. a conference call). Another possibility to classify communication (channels) is provided by the differentiation between synchronous and asynchronous conversations.

4.3.3.1 Synchronous Communication

In recent years various advanced synchronous communication technologies have been developed. The notion of synchronous communication describes direct, real-time communication between the participants of a conversation. Thus knowledge workers are supposed to be able to communicate directly on the CKWS, e.g. to resolve an issue or to directly exchange information. Commonly known examples are instant messaging, phone and video calls which are used for the direct one-on-one conversation. The common technology of chats and (audio/video) conferences are used to integrate more than two people into a common conversation. Hence synchronous communication can be distinguished by considering the amount of involved persons and of course the certain media in use.

Naturally, the quality of communication services play an important role as synchronous communication channels generally have to fulfill a maximal end-to-end delay. Knowledge workers likely appreciate high quality communication channels in all facets to exchange information wherever they are and whatever device they use.

4.3.3.2 Asynchronous Communication

In comparison, asynchronous communication does not require the conversation's participants to be present at the same time. Instead the content of communication, e.g. a text message or video, is therefore appropriately cached to be perceived by communication participants later on. The most common example of a asynchronous communication system is represented by ubiquitous e-mail systems. Other commonly known examples are discussion forums, wikis or weblogs. Regarding multimedia content podcasts, photo galleries, video stream or entire media libraries also belong to the term of asynchronous communication.

Generally a CKWS which offers the right asynchronous communication possibilities context-based, achieves a higher knowledge workers commitment. But the provision is logically intertwined with the provision of content for knowledge workers as asynchronous communication can be regarded as content, too. Thus the transition between those two categories is fluent and the combination of content items and communication can achieve beneficial effects. As an example, electronic messages interchanged between two knowledge workers on a CKWS can yield a benefit as soon as these messages are closely presented in the context of content the conversation is about. A further example for communication in work context can be found by so-called real-time group editors [18]. These editors aim to support users in collaborative writing or programming by synchronous access on content in combination with associated communication channels (e.g. a text messenger) to coordinate the writing process and to accelerate progress.

4.3.3.3 Social Communication

Since the turn of the millennium a great variety of newly developed web-based social communication software have been offered, strongly connected with the extensively used term *"web 2.0"* (cf. Section 5.1) and the previously presented requirements of synchronous and asynchronous communication. New shapes and processes of social interaction and communication have been developed on the base of early contributions in the area of CSCW. These technologies have been already widely adopted by a broad range of consumers in recent years. Consequently a lot of these technologies are increasingly requested by users in business context as well [62]. Especially knowledge workers are supposed to profit from an integration to discuss plans, intermediate results and general issues in the referential field of action. This is also underlined by the theory of knowledge management and knowledge generation presented in Section 2.2.2.1.

That's why a CKWS has to provide an integrated, self-regulating social communication ecosystem fostering the beneficial exchange of ideas and thoughts. Moreover a CKWS needs to provide beneficial features like team and community support, advanced shapes of social communication processes (e.g. decision finding processes, surveys, digital blackboards) or the establishment of so-called expert networks. Referring to the development project (UC1), these integrated features could yield an acceleration of dynamic, communication-based problem-solving processes by stable, social and multidimensional communication on the one hand side. Expert networks, on the other hand side, could help in dynamically advertising work packages based on the offered competences of available knowledge workers. Furthermore knowledge workers can exchange ideas and problems with like-minded knowledge workers, receiving valuable feedback which is also traceable and documented in a context.

4.3.4 SR4: Awareness Support

Drawing upon the presented communication requirements, the *awareness* about where experiences and expertise reside (*"who knows what"*) has to be regarded as a crucial factor for knowledge workers. Responsible knowledge workers obviously need initial and constant awareness information about involved knowledge workers, their capabilities or their currently conducted actions. In this context Gutwin and Greenberg [63] shaped the term of *group awareness* to be *"the up-to-the-minute knowledge of other people's activities that is required for an individual to coordinate and complete their part of a group task."*.

But not only for coordination aspects, awareness information is certainly equally important for proper communication and content sharing among knowledge workers. Section 2.2.2.3 and dimension D3 (cf. Section 3.3.3) motivate that knowledge workers essentially need to be aware of their conversational partners' foreknowledge and context as much as possible to ensure proper understanding. Especially when conversational partners do not know each other yet or knowledge workers are spatially distributed (dimension D5), awareness information plays an important role to foster the communication quality.

To establish a proper awareness support for knowledge workers, Gutwin and Greenberg provided a list of possible awareness information which can be leveraged in consideration to a CKWS [64]:

- *Presence:* information about participating knowledge workers in the work context (e.g. in a specific CI).
- *Location:* information about locations where knowledge workers are working.
- *Activity level:* information about the intensity knowledge workers contribute in current activities.
- *Actions:* information about actions currently taking place (CI).
- *Intentions:* information about intended actions and resources probably involved (CI).
- *Changes:* information about current modifications (CI).
- *Objects:* information about objects/resources being in use (CI).
- *Extents:* information about scopes of other knowledge workers.

- *Abilities:* information about the capabilities of knowledge workers.
- *Sphere of Influence:* information about the sphere knowledge workers can commit changes.
- *Expectations:* information about what other knowledge workers expect from a certain knowledge worker.

Of course the types of ascertainable awareness information need to be carefully selected, adjusted and embedded in the CTs (and its user interfaces) to properly support knowledge workers during their collaboration. Otherwise knowledge workers are likely overwhelmed by the available awareness information. Whether proper algorithms can determine the right information context during the CI's execution or search possibilities are more appropriate has to be subject of future research. Finally the acquisition of awareness information needs to be considered too: generally information are either provided voluntarily (push principle) or information are acquired through monitoring and sensors (pull principle). The latter concept obviously conflicts with privacy and labor law issues which have to be naturally handled appropriately (compliance, cf. Section 4.3.6).

4.3.5 SR5: Analytics Support

As content is continuously added to a CI, involved knowledge workers obviously require proper content management functionality on the one hand side. On the other hand side *analytic* features are requested to cope with the challenges of constantly growing information and their interrelations. Thus requirements considered analytic features are naturally connected with the knowledge actions types and degree of information interdependencies (dimensions D1 and D8, cf. Section 3.3.1 and 3.3.8) As an example, while inspectors are gathering information they require functionality to frequently analyze the information relationships to derive and determine future actions (UC2). Thereby smart analytic features could foster the derivations, extraction and visualization of key information out of a huge and intransparent mount of information. As a further example, secured documents taken from suspects could be digitized and subsequently analysed to extract relevant information as e.g. frequently mentioned persons. The names of the persons could be verified in the current context and so further inspections can be taken up.

Furthermore analytic functionality can be leveraged to establish and refine CTs: collaboration records and especially their history could be analyzed in order to identify content elements or communication and coordination elements which are likely necessary to be integrated into a CT for future endeavors. To foster the assessment *business processes mining* tools could be leveraged as they could provide retrospective process models which can be analyzed additionally [65]. Besides internal analyses of collaboration records, a solution can also integrate existing data-warehouses or business activity monitoring to allow knowledge workers to track and analyze the progress of related business processes. Thereby the correlation between analytics and awareness support is illustratively underlined.

4.3.6 SR6: Compliance Support

The last requirement category of *compliance* comprises the knowledge workers' duty to adhere to a wide range of different regulative constraints. Generally compliance requirements are logically connected with the performed knowledge actions types as well as the surrounding organizational frame (D1 and D4, cf. Section 3.3.1 and cf. 3.3.4). Importantly mentionable regulations are security precaution (i.e. encryption, authentication and signatures), confidentiality, traceability, codes of conduct, domain- or company-specific business rules and of course various laws. These regulations naturally limit the knowledge workers' sphere of influence and unfortunately these regulations are also often subject of modifications (e.g. new laws). Furthermore compliance is generally connected to the other requirements aspects which have been presented so far. For instance insurances naturally need to document customer interaction records on the base of legal obligations. Furthermore they are limited in leveraging these records for analytics as they need to consider privacy issues. A CKWS thereby has to ensure that compliance regulations are properly implemented into the solution on the one hand side and the adaptive adjustment of these regulations on the other hand side.

Due to the dynamic nature of CKW, including optionally new participants and constantly new content in the collaborative process, static rules are likely inappropriate and adherence to regulations in general represents a challenging task. Knowledge workers need to be able to define business rules in a easily understandable and maintainable way to do justice to the unfolding and evolving character of CIs. An easy example could be the restraint to use several technologies during the development project due to possible intellectual property infringements (UC1). Finally such business rules are important for coordination requirements as well. For instance, constraints like limited access or instructions to treat a topic confidentially (e.g. four-eye principle) obviously influence the possible coordination of knowledge workers, too.

4.4 Appraisal

In summary this section has characterized a CKWS aiming at the holistic support of collaborative knowledge workers by the provision of sophisticated support based on the approach of a CKWL. To ensure such a support a system needs to satisfy general requirements as well as versatile system-specific requirements. Thereby a CKWS symbolizes the focal point of collaboration for knowledge workers (platform) and, hence, it needs to widely cover a really challenging range of requirements in the main areas of content, communication, coordination and awareness. Based on the presented requirement categories a conceptional architecture of a CKWS is presented in Figure 4.6. It thereby illustrates the important interplay between CTs, CIs and CRs as well as the requirements' main categories. Moreover the integration of knowledge workers as well as the integration of data sources respectively information systems is illustrated because both integrations directly refer to the general requirements a CKWS has to fulfill.

Naturally a lot of subordinate requirements have not been brought up as the requirements merely touch the different requirements categories - a lot of detailed demands and potential issues have not been addressed. However the possible quantity of requirements might be that enormous that some people could call the CKWS an (impossible) allrounder. Actually this insight is highly valuable and it can already brighten everybody's wits to closely examine which parts of such a system can already be established by existing technologies and which parts still have to be subject of future research. In this context the subsequent Section 5 presents technologies which could be already utilized for a CKWS.

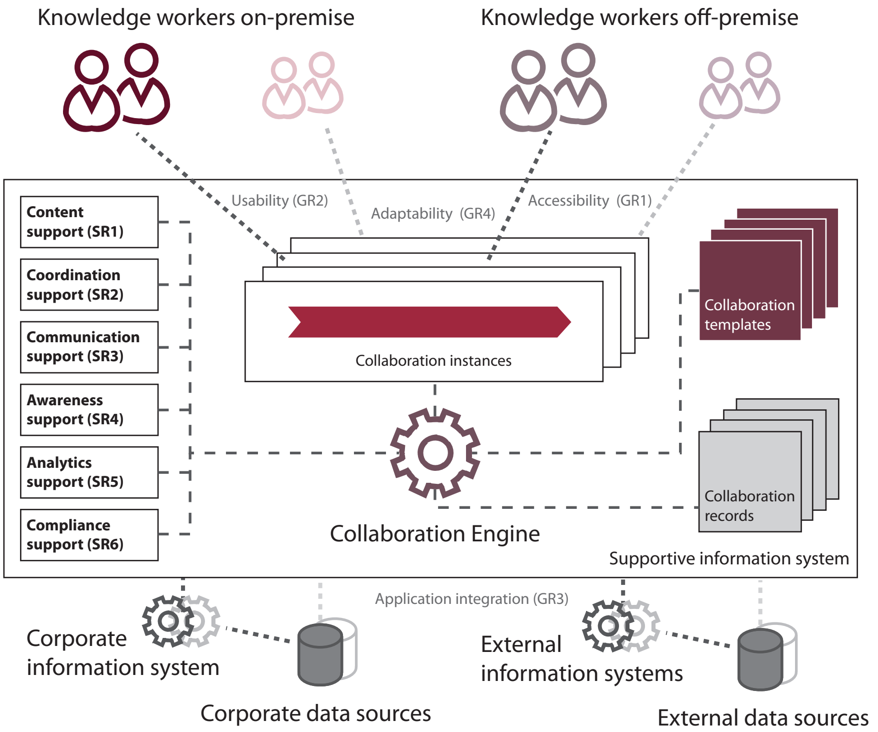

Figure 4.6: Conceptional overview of a CKWS

5 Technologies for an Information System

The saddest aspect of life right now is that science gathers knowledge faster than society gathers wisdom.

Isaac Asimov (1920 - 1992), Russian-American biochemist and famous science fiction writer.

After the introduction and discussion of requirements for a CKWS in Section 4, core technologies addressing essential aspects of the requirements are discussed in the following. In general these technologies belong to at least one of the three ensuing categories: *social software*, *constraint-based BPM technologies* or *enterprise content management* (ECM).

Technologies in the category of social software (cf. Section 5.1) are supposed to satisfy requirements regarding adequate communication support, awareness information and content respectively knowledge management. Furthermore they additionally address the important aspects of usability and accessibility. Constraint-based BPM technologies (cf. Section 5.2) might satisfy requirements in the area of agile coordination as well as awareness and compliance support. Finally ECM technologies (cf. Section 5.3) aim to holistically support people in the management of an overwhelming variety of content. In this context, case management is presented as a familiar approach to offer an integrated and context-related support for cases. A short appraisal in Section 5.4 rounds off the discussion of technologies.

5.1 Social Software

As discussed in Section 4.3.3.3, today's pervasive social communication technologies are strongly connected with the development of web technologies known as *web 2.0*. Discussing the term, Koch and Richter conclude that web 2.0 has to be considered as a combination of

- the continuous improvement and intensified acceptance of various web technologies, like Web Services, Ajax, RSS, XLST,
- increasing modularity and new types of applications offered as web-based services,
- an increasing orientation towards the needs of individuals using web-based applications, e.g. improved usability,
- a social movement characterized by broad participation and deliberate self expression.

Summarizing web 2.0 reflects a certain maturity level of web-based technologies which have become gradually pervasive and accepted. People are increasingly able to interactively and collaboratively contribute information while they used to merely consume web content before. Based on the improvements and further technological progress (higher bandwidths, powerful mobile devices and virtualization) a variety of new web-based, social applications and technologies have been developed which feature possibilities to intensively collaborate and exchange ideas virtually and interactively.

Thereby social software is often informally described to be software systems supporting human communication and collaboration [66]. The author decided to rely on a more specific definition on which the following Definition 5.1 relies [62]:

> **Definition 5.1** ***Social software*** *describes systems leveraging network and scale effects to facilitate direct and indirect interaction between users across-the-board (coexistence, communication, coordination, narrow collaboration). Further these systems map their users' identities and support their mutual relationships.*

Definition 5.1 underlines why the inclusion of social software can be valuable for a platform supporting collaborative knowledge workers. Social software's main purpose is to bridge spatial gaps between its users by providing state-of-the-art web-based social communication and general collaboration possibilities. Thus the integration of social software can especially satisfy requirements in the areas of accessibility (GR1), usability (GR2), coordination (SR2), communication (SR3) and awareness (SR4). Through the mapping and management of their identities and mutual relationships, knowledge workers could generally accelerate the establishment and the resumption of communication processes.

Evaluating social software applications in use, the *main fields* of application can be categorized into five classes [62]:

i) Blogs[1] and microblogging

ii) Wikis and group editors

iii) Social tagging and bookmarking

iv) Social networks

v) Instant messaging

A consideration of the supported basic functionalities allows a further consolidation. Hence the following list offers an overview of these functionalities and their corresponding support through the mentioned application classes (figures in braces):

- Web-based information management (i, ii and iii)
- Identity and relationship management (iv and v)
- Interaction and communication (iv and v)

Based on this principle categorization the different application types are supposed to be briefly discussed subsequently. However the following Section 5.1.1 comprises wikis and social tagging and omits blogs as they share a significant overlap with wikis regarding the creation and management of content. In addition they are primarily cut out to be a personal communication channel.

Furthermore the last two categories are summarized in Section 5.1.2 due to the fact that today's social networks integrate a broad range of interaction and communication technologies (e.g. instant messaging).

[1] also known as weblog

5.1.1 Information Management

In the following passages *wikis* and *social tagging* are to be presented, providing content and knowledge management functionality which could be leveraged for the usage in a CKWS. Wikis generally offer a possibility to easily add content to an existing content base and also to create linkages between content. Moreover they naturally offer collaborative editing features which are crucially needed for the support of collaborative knowledge workers. The workers obviously require functionality to collaboratively manage content of all kinds in the context of the CIs they are involved in (cf. SR1, Section 4.3.1). Social tagging refers to an advanced tagging concept which can combine individually added tags to create meaningful semantic information relationship networks (cf. SR5, Section 4.3.5).

5.1.1.1 Wikis

A *wiki* is a web-based database enabling their users to collaboratively add, update and organize interlinked, unstructured content in the shape of hypertext. Cunningham, the inventor of the first wiki software, originally expressed that a wiki is supposed to be *"the simplest online database that could possibly work"* [67].

As multiple users usually contribute to the same topic wikis can be regarded as *group editors*. Thus wikis provide technical features like advanced concurrency control as well as a sophisticated versioning and reviewing concept. To integrate as many users as possible into the authoring process, wikis provide editors abstracting from technical details. Thereby a wiki syntax widely abstracts from the markup language HTML, but users naturally still need to look up instructions first. Based on the web 2.0 improvements, efforts have been intensified to provide modern web-based WYSIWYG[2] editors in relation to wikis. State-of-the-art WYSIWYG editors are also strongly needed for a CKWS as knowledge workers have to be enabled to add and edit content of various types directly in the context of a CI (SR1, cf. Section 4.3.1.2). An illustrative example for such an editor is provided by the open source group editor etherpad [68] which even enables users to simultaneously edit content and communicate with each other.

[2] Acronym for *"What You See Is What You Get"*.

Koch and Richter provide several wiki application scenarios confirming a potential beneficial value regarding the established knowledge management requirements (SR1) in Section 4.3.1.3 [62]. Wikis are mostly used to collaboratively document business-relevant knowledge like best practices, frequently asked questions (FAQs) or general insights. Development projects (e.g. UC1, cf. Section 3.1.1) already leverage wikis to document and centrally provide project-related content as well as to collaboratively clarify misleading notions. Wiki users are supposed to voluntarily externalize their gathered knowledge to establish a common knowledge base which people who are involved in similar scenarios can benefit from. Thereby content residing in wikis represents a part of organizational knowledge which remains even when knowledge workers leave projects.

Generally wiki software relies on further principals which can yield additional benefits for a CKWS. Based on their knowledge and expertise, wiki users individually connect content to related content via hyperlinks. Based on these associations as well as article structures and meta data, analytics can be performed to gather valuable information dependencies and even semantic webs. Management of information interconnections is a crucial requirement in the investigative UC2 (cf. Section 3.1.2) and is also addresses in requirement SR5 (cf. Section 4.3.5). An applicable sample of this concept is represented by the project DBpedia [69]. In relation, Section 5.1.1.2 introduces the concept of social tagging which addresses the collaborative attribution of content with meta data.

5.1.1.2 Social Tagging

Social tagging describes *"the process by which many users add meta data in the form of keywords to shared content"* [70]. In contrast to classical tagging and indexing approaches in the context of enterprise content management (cf. Section 5.3.1), social tagging leverages users' personal needs to create a classification of content items and combines their added keywords. In general, the adding of keywords to content is neither exclusive nor hierarchical. So social tagging can be beneficial in situations users can not easily apply these classical structures. Based on already added keywords, social tagging technologies can condense and combine tags (e.g. the most frequent keywords) of a certain object to suggest keywords to users who intend to tag a certain object as well.

Social bookmarking applications can be regarded as a common example for social tagging. Applications widely in use are, for instance, *delicious* or *digg* [71, 72]. The concept of social bookmarking comprises adding, sharing and organization of bookmarks referencing web-based content on a central platform. The adding of tags to web bookmarks allows users to compare and find related, possibly relevant bookmarks to related content afterwards. Apart from the tagging of websites, social tagging can be used for all kind of objects like pictures, videos and even scientific articles as long as the objects can be uniquely identified by an unique identifier (e.g. an URI[3]). Identifiers enable the applications to suggest key words to users of the service during the indexing process of a single object. For the utilization of social tagging in the context of a CKWS, the identification and comparison of content items is naturally an issue which has to be resolved.

The benefits of social tagging for a CKWS is the enrichment of content with keywords. They describe the meaning of content on the one hand side (faster retrieval) and contextually classifies related content on the other hand side (comprehensive structure). Through the adding of keywords, knowledge worker could quickly gather impressions without studying content thoroughly. Furthermore content gradually becomes comparable, related and interlinked – a crucial requirement (SR1 and SR6, cf. Sections 4.3.1.2 and 4.3.5) if the presented use cases are considered again. Additionally, content in a specific CI that shares a high percentage of identical tags with other content in related CIs (common CT) can be linked and provided in a collection. Knowledge workers could thereby quickly access subject-related content without looking for it intensively. Potential weak points of collaborative tagging are the mentioned comparison of content items, the application of synonyms and homonyms by users and a missing opportunity to rate the importance of keywords.

5.1.2 Social Network Sites

Since their rise at the end of the 1990s, *social network sites* (SNSs) have increasingly attracted and integrated millions of users on their platforms mainly in the shape of public networks or business networks. Comparable to prior social software examples, SNSs have strongly profited from web 2.0 developments allowing them the provision of interactive and easily

[3]Uniform resource identifier

usable functionalities via a web-based access. SNSs' purpose is to empower users to map and manage their real-world social networks on a web-based, interactive platform. Boyd and Ellison provide a definition of social network sites [73]:

Definition 5.2 ***Social network sites*** *are defined as web-based services that allow individuals to construct a public or semi-public profile within a bounded system, articulate a list of other users with whom they share a connection, and view and traverse their list of connections and those made by others within the system.*

In general, SNSs allow their users to create and maintain personal profiles containing various personally related information. Apart from basic information (e.g. name, date of birth) users have the possibility to deposit additional information to share, e.g. current employer, academic degrees or personal skills/expertise. The provision of information enables other users to easily find known people in order to establish respectively document connections on the platforms. Once a connection has been established a single user is able to easily communicate to his connected user, he might track the user's profile and status updates.

As a main purpose users may bridge spatial as well as resulting informational gaps to others users. Therefore SNSs currently offer a wide range of additional features to increasingly attract users to their platforms, e.g. communication about common interests in dynamic *groups*. Moreover multiple rich communication channels have gradually been tightly integrated (cf. Section 5.1.2.3) to allow users to intensively communicate with each other. Moreover, some SNSs already extended their network to be an application platform allowing external developers to create and deploy applications.

As a consequence, SNSs can address a CKWS's general requirements in the area of accessibility (GR1), usability (GR2) and application integration (GR3) (cf. Sections 4.2.1-4.2.3). Furthermore, SNSs naturally satisfy a wide range of specific requirements in the areas of communication (SR3) and awareness (SR4) (cf. Sections 4.3.3 and 4.3.4).

As a consequence, the main functionality of SNS is discussed more accurately in the following. Definition 5.2 implicitly refers to two main basic features of SNSs which also jointly symbolize a class of social software's basic functionality: identity and relationship management. Furthermore, SNSs' communication and interaction possibilities are also discussed in Section 5.1.2.3 as these features are also especially relevant for context-related communication in CIs provided by a CKWS.

5.1.2.1 Identity Management

Crucially for the success of a SNS, users are supposed to voluntarily provide information about themselves. Based on personally related information, the networks' users can find users they already know, or they can renew relationships or even make an acquaintance. Apart from textual information users are often allowed to upload pictures or even videos to enhance their personal profile. Regarding privacy issues, SNSs nowadays allow to define sophisticated access rights for personal information.

Tightly connected with the personal profile, social networks frequently provide the possibility to communicate with connected people via status messages – this function is precisely named microblogging. Based on the principles of blogs, microblogging keeps connected users up-to-date with short messages. Besides plain textual messages users can also share web links, pictures, video and even their current location. As for personal information users usually define the audience of such posts.

As motivated for requirement SR4 (cf. Section 4.3.4), a high degree of awareness is a crucial need for collaborative knowledge workers. SNSs' identity management can thereby offer clear benefits. If knowledge workers autonomously took care of their virtual business profiles, already available organizational models could be enhanced in order to allow knowledge workers in charge to find required professionals faster and more effectively. Moreover the deliberate provision of status information via microblogging could also be utilized to keep other workers up-to-date with information like project updates or an absence for a certain period of time.

5.1.2.2 Relationship Management

The provision of profile information is a prerequisite to enable users to establish a connection in SNSs. Boyd examined that most of the people do not perform networking on a platform, instead they merely document their relationships, they appreciate to receive status updates and they use the platform to stay in contact as well as to communicate [73]. Regarding the connections between users, SNSs often offer different types: direct connections between users can be generally distinguished in unilateral connections and mutual connections. By unilateral connections users are allowed to *follow* other users without the need of an up-front acknowledgment of the connection. Further indirect connections are established through the users' memberships or interest in virtual objects (e.g. groups or pages). Social networks also often allow users to classify their mutual connections to other users. Thereby users can manually or automatically assign befriend users to lists which can be utilized afterwards to specify access rights to personal information or status messages.

If a corporate SNS is closely integrated into a CKWS, the establishment and management of relationships to other knowledge workers could foster the communication between them (SR3) as well as it can yield additional awareness (SR4) about actions performed by connected knowledge workers. Through connections to knowledge workers who are befriend or just involved in common CI, an individual can constantly get updates regarding status information, new posts and new established connections. In addition subject-related groups and pages could allow knowledge workers to access shared content spaces where thoughts and common interests are discussed. The possibility to inspect and traverse the connections of users can be regarded as a benefit for knowledge workers too, as it can additionally increase the worker's stock of contextual awareness information. In this context the interdisciplinary research field of social network analysis can be referenced to. Based on multiple (corporate) data sources like a SNS or organisational models, social network analysis software can provide valuable information and visualizations of complex social interdependencies[4] (CKWS's requirement SR5).

5.1.2.3 Communication and Interaction

Most SNSs traditionally offer an integrated message service which enables users to quickly exchange information. In addition popular SNSs have increasingly integrated additional, sophisticated communication and interaction functionality in order to attract more users and to gain a competitive advantage to other networks. Regarding the communication

[4]A running demonstration can be inspected in [74].

requirements for the support of collaborative knowledge workers, some SNSs already provide a broad variety of synchronous and asynchronous communication channels.

Especially instant messaging (IM) functionality has been widely integrated as this social software application class already shares close commonalities with SNSs. IM is denoted as a communication method allowing two or more users to communicate primarily text-based in real-time. Normally users are required to use the same client software in order to establish a communication session. Comparable to SNSs, IM users generally manage their own contact list, usually including people they already know and providing information about the current status of the user (online, away, offline, etc.). Furthermore users can deposit personal information in a profile to enable other users to find them easily. Since SNSs primarily offer identity and relationship management they logically enhanced their platforms to support IM as soon as the technology could be stably provided web based (typically based on AJAX).

In recent years the constantly increased bandwidths have also fostered the development and distribution of *Voice over Internet Protocol* (VoIP) applications. People are thereby allowed to establish high-quality audio communication or even multimedia sessions. Operators of large-scale SNSs like Facebook [75] and Google plus [76] have recently published integrated video conferencing features to increase the possibilities of communication. Apart form the integration of communication channels SNSs have also integrated other social software application as already seen for status updates (i.e. microblogging). Social tagging is included in some SNSs in order to enable users to tag uploaded pictures. Besides pictures, some SNSs offer users to upload various multimedia files they can share. Related to the objects, users are allowed to drop comments and start asynchronous text-based discussions providing a possibility of context-related interaction.

In summary the increasing communication and interaction concepts provided by SNSs can be attached value considering the establishment of a CKWS. Especially for the requirements of communication (SR3), in particular social communication, SNSs already offer various concepts which could be adopted. Nonetheless most SNSs still focus on the interaction of individuals during their leisure time. For an adequate corporate application, SNSs' interaction and communication concepts probably need to be adequately adapted to fulfil corporate requirements and, in particular, compliance demands like privacy and labor law in general.

5.2 BPM technologies

Since the very early days of BPM, community members have discussed general support limitations and especially flexibility issues of process-oriented approaches. Scientists have released a wide range of publications addressing approaches to expand the degree of flexibility and the general support of business processes accompanied by a BPMS (e.g. [77, 78, 56, 79]). Especially when adaptions of running process instances are required, challenging problems of different types have to be resolved.

Strict correctness requirements, which BPMSs usually need to impose in order to ensure proper execution and completion of enacted business processes, are the reason why flexibility will always be limited for process users facing highly dynamic situations during run time [80, 81]. Thus researchers are naturally interested in approaches aiming to support users whose processes cannot be supported adequately due to their needs for a high degree of flexibility (e.g. knowledge workers). Though these approaches generally break with the basic principle of BPM to design business process models by a finite set of activities which are connected via sequential flow constraints.

While so-called *constraint-based business processes* generally feature a finite set of activities for a certain business process as well, the activities can be connected by constraints *merely* restricting the possible execution order of the activities. Thus the defined activities are supposed to be finally arranged by the involved users themselves during the process run time accordingly.

Apart from a constraint-based approach, BPM research has increasingly focused on the idea of *data-driven* business processes too (cf. [82, 83]). Thereby activities and their constraints are not explicitly designed in business process models anymore. Instead the process-related support is generally controlled on the base of data which is involved and required during the process executions. Therefore the support of the involved users is supposed to be increased and inventors of the approaches intend to overcome implicit drawbacks of activity concentration like the lack of flexibility and a missing view on the involved data [84, 85].

In summary the presented approaches can be classified into categories which are depicted in Figure 5.1. Especially the right part of Figure 5.1, exposing constraint-based and data-driven process support, central access to content (content-centric support) as well as communication-centric collaboration, can be regarded as promising in reference to CKW. As social software and its communication support has been already presented in Section 5.1, subsequent Section 5.2.1 presents details and potentials of constraint-based modeling for CKW. The data-driven approach is further discussed in Section 5.3.2, dealing with the central provision of content and case management.

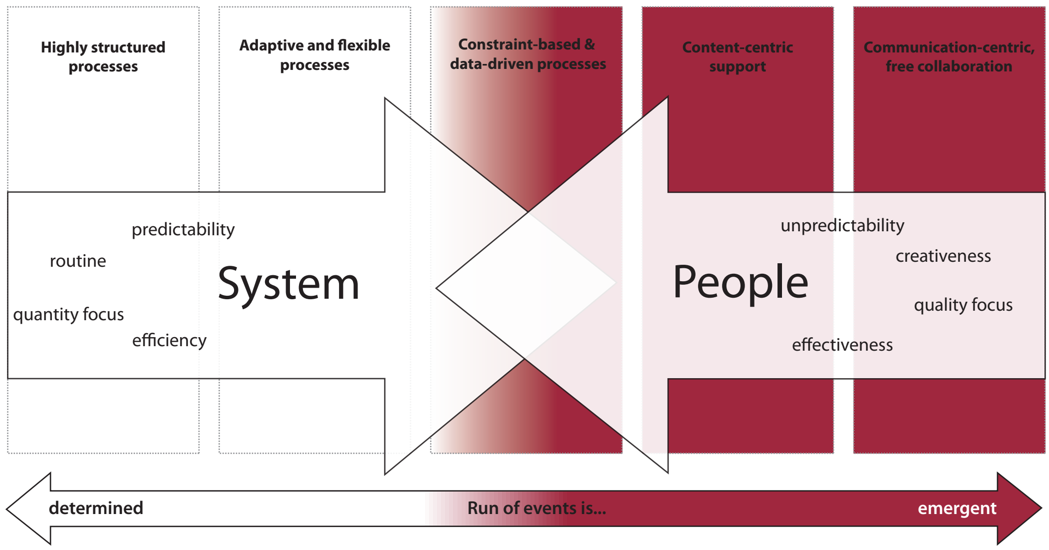

Figure 5.1: Process-related approaches and their power of decision

Moreover Sections 5.2.2 and 5.2.3 introduce the technologies of complex event processing and business rules. Both are presented in the context of BPM as these technologies are often leveraged to support standardized business processes. However, these technologies are supposed to provide valuable benefits for the support of collaborative knowledge workers, too.

5.2.1 Constraint-based Business Process Management

Addressing knowledge workers' requirements for an agile coordination support (SR2, cf. 4.3.2.3), the approach of constraint-based business process management is presented in the following. Generally this approach contrasts the classical way to design business processes [86]. While imperative business process models closely predefine how activities have to be performed (similarly to imperative programming), constraint-based process models generally address what should be done. Therefore the activities, which can be performed during a process execution, are specified at first and advanced constraints are then applied to the activities, restricting the execution order and prevent undesired execution behavior (cf. Figure 5.2).

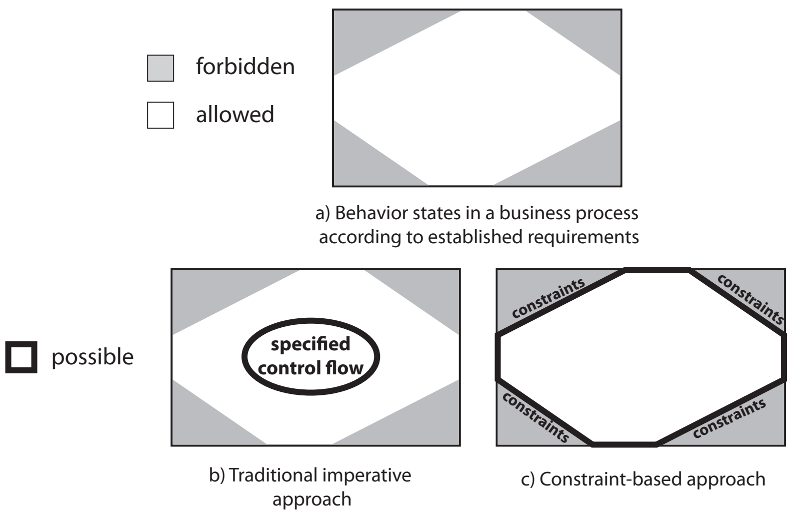

Figure 5.2: Constraint-based modeling approach, based on [86]

Figure 5.2a describes the fact that, independently from the chosen approach, certain general requirements have to be fulfilled by a business process model. Logically a business process' activities execution behaviors can be distinguished between allowed and forbidden states (cf. Figure 5.2a). Traditional business process models merely cover a part of those allowed states (cf. Figure 5.2b) whereas constraint-based process models are able to address the entire space of allowed execution states (cf. Figure 5.2c). Based on these insights, Definition 5.3 formally introduces constraint-based process models according to [86].

Definition 5.3 *A **constraint-based business process model** cm = (A,C_M, C_O) consists of a finite set of activities A as well as two finite sets of constraints C_M and C_O prohibiting undesired execution behavior. C_M symbolizes mandatory constraints that have to be complied with, whereas C_O represents optional constraints that are supposed to be obeyed.*

As (collaborative) knowledge workers actively determine the course of action, the idea of constraint-based business processes can be naturally promising. In theory, constraint-based business process models could be utilized to configure to a set of activities for a CT and the knowledge workers themselves could specify the execution of the activities during the derived CIs' run time. Furthermore knowledge workers might autonomously define activities, constraints and allocations of work to continuously plan in an agile way. To demonstrate the principles and benefits of constraint-based business processes in relation to a CKWS, a concrete knowledge worker example originated from the medical domain is presented in the following. In order to foster an easy understanding, only mandatory constraints are applied – representing constraints between activities which have to be complied with.

It shall put the case that a fictitious fracture treating process is supported based on a constraint-based business process model. Referring to Section 2, the treatment of a patient's suffering is generally considered as a CKW. Presumably, several activities are identified frequently requested during a fracture treatment process: a patient can be examined (activity abbreviation *Examination*), an X-ray of the patient can be taken (*X-ray*), medicine can be prescribed (*Medicine*), a surgery can be performed (*Surgery*), a cast can be applied (*Cast*) and physiotherapy can be prescribed (*Physio*). Theoretically the execution ordering of the activities is dedicated to the attending physicians, but there are restrictions involved doctors have to comply with: a patient examination is always performed at the very beginning of the treatment process. If a surgery needs to be performed, an X-ray has to be taken before. After a surgery, a patient is supposed to receive physiotherapy. Finally, the application of a cast is forbidden if a patient is supposed to get a surgery afterwards.

Figure 5.3 graphically depicts the activities and their constraints based on the notation DecSerFlow [87]. In accordance to the established constraint-based model, attending physicians could autonomously determine how often and in what ordering they intend to perform the provided activities.

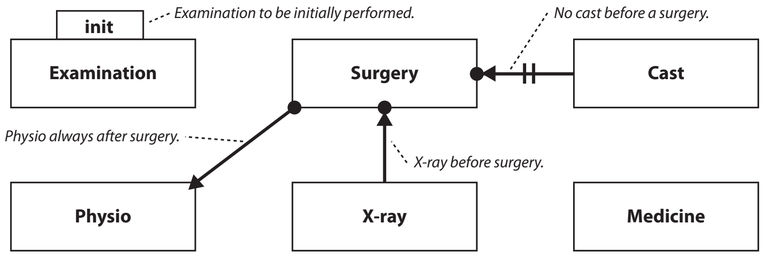

Figure 5.3: Example of a constraint-based business process model

As a consequence CTs could be enriched by predefined activities being identified during the orientation phase of the CKWL. The corresponding activities could be adequately configured with underlying data access, integrated applications or possible knowledge workers. Through the application of constraints on the activities, forbidden execution behavior is restricted and thereby compliance rules can be applied as well. Hence constraint-based business process models have a direct relation to a CKWS's compliance requirements (SR6, cf. Section 4.3.6) and logically to the adherence to business rules. Rules in general are considered to be the basics for the following Sections 5.2.2 and 5.2.3.

5.2.2 Complex Event Processing

As discussed in Section 4.3.4, awareness (SR4) in all its facets is considered to be an important requirement for a CKWS. Logically awareness information are also needed in the context of business processes accompanied by BPMS. Process instances are often triggered or significantly influenced by external and internal events. Hence these events have to be made visible to a BPMS, enabling the system to immediately deliver events to corresponding process instances. But events can be generally quite versatile due to granularity issue and they can occur in different manners. For instance, a received sales order can be theoretically considered as an event as well as a mouse click on an user interface. The intention of *complex event processing* (CEP) is to detect, to analyze and to combine related events in order to compose a semantically higher and meaningful event [88]. As an example, the medical scenario presented in Section 2 can be referenced: if a patient is connected to several sensors publishing periodically data, CEP can be used to detect potentially dangerous situations and hence to inform the responsible doctors in time.

Hence classical fields of application of CEP are sensor networks, *business activity monitoring* (BAM) and the analysis of market data. BAM involves the supervision of important business processes and business resources to detect opportunities and risks. Therefore various events are collected, analyzed, aggregated and finally denoted in the shape of key performance indicators. Market data can also be considered as a source of constant events (updates) and hence analyzed to identify trends and opportunities. Obviously CEP strongly relies on a proper integration of the data sources and the incoming events are technically evaluated based on rule sets. Hence the relation of CEP to business rules is picked up in the following Section 5.2.3 again.

In summary, the creation of meaningful awareness information can obviously yield benefits considering the support of collaborative knowledge workers. Events, which usually occur in various corporate system as well as internally in the CKWS itself, can be aggregated and processed to meaningful information provided by the CKWS to the knowledge workers. Thereby the knowledge workers' degree of context-related awareness can be significantly increased and an overwhelming information flood can be omitted. Furthermore content, which is deliberately added by the knowledge workers to a CI, could be also interpreted and analyzed as events. For instance responsible knowledge workers could receive messages as soon as considerable information has been added to a CI.

5.2.3 Business Rule Management

A business rule *"is a directive or a guideline influencing and governing business behavior"* [89]. Generally rules can be found in every company, a simple example of a business rule deployed in imaginary sales department could be: *"every contract granting a discount* *higher than 5 % an formal approval of the sales manager is requested"*. The idea of *business rule management* (BRM) is characterized by separating respectively extracting business rules from their operative environment, e.g. applications, system and business processes, in order to manage them centrally. Generally the intention of managed business rules is to increase the agility to change business rules, to foster the quality of services or products by predefined decisions and to ensure an optimum of *compliance to legal and corporate regulations*. Furthermore the responsible IT departments are prevented to deal with problems and efforts which are usually caused by manual changes of systems, application, business process and so forth. Lastly the creation of a central business rules stack additionally contributes to the corporate knowledge management as it fosters organizational transparency.

Usually business rules are expressed in a general *"if condition then action"*-pattern. However for proper creation and management of business rules markup languages (e.g. RuleML [90]) or graphical notations (e.g. decision trees, decision tables) are used. Considering the application of business rules, a *business rule management system* (BRMS) containing a rule engine (actual an inference engine, cf. [91]) inspects whether the condition of rule is satisfied to execute the predefined action. To resolve the similarities of BRM and CEP, both approaches are related as they rely on the utilization of defined rules and even on forward chaining: an action, caused by a rule, can trigger further rules through satisfying their conditions. As the main difference CEP focuses on the processing of occurring events whereas BRM primarily depends on the evaluation of information (e.g. the contract including the discount) considering the defined condition.

While CEP can be leveraged to gather additional awareness information, BRM could be theoretically utilized to ensure various compliance regulations knowledge workers have to comply with (SR6, cf. Section 4.3.6). But the emergent nature of collaborative knowledge work obviously causes a central problem: the dynamic and free inclusion of new (often widely unstructured) content to a CI on behalf of the knowledge workers naturally limits the applicability of business rules as the exact conditions of the rules can be hardly foreseen. Nonetheless business rules can be applied for content which is integrated in a CT up-front. The application of rules for added content might be possible if rules could be defined rather fuzzily to allow the identification of possible conditions in unstructured documents (data, text mining). Naturally this idea logically raises questions about performance and feasibility. Whether this approach and business rules are promising or unfeasible for a CKWS has to be subject of future research.

5.3 Enterprise Content Management

After the consideration of technologies widely addressing the requirements of communication, coordination, awareness and compliance, this section mainly refers to the content support of collaborative knowledge workers. Considering the characteristic C2 (cf. Section 3.2.2), CKW is generally emergent and its course of action is unpredictable in detail, an exact prediction which type of content (e.g. data types, documents) is required is not possible. Similarly a detailed appraisement of the exact information flow between the collaborative knowledge workers is logically also not feasible. So based on the requirements mentioned in SR1 (cf. Section 4.3.1), a CKWS is supposed to integrate as many relevant data sources as possible. Thus CTs can be equipped with predefined selection of possibly required content and derived CIs can offer this content to the knowledge workers during the CIs' run time. Furthermore sophisticated content management functionality has to be offered to allow knowledge workers to add, edit and generally manage content during their collaboration. But this is aggravated by the fact that there is still a considerable quantity of corporate information respectively documents not being available digitally. According to statistics, the share of digitally available corporate information was estimated to be merely between 35% and 45% in 2001 [27].

Although the proportion has likely grown until today, general integration of paper-based content into a CKWS has to be ensured as well. Therefore *a CKWS has to be embedded in an enterprise content management initiative addressing the entire lifecycle of corporate unstructured information*. Moreover the CKWS itself can be an important part of such an initiative as it features a constantly increasing stock of information respectively knowledge. To structure the ongoing discussions, enterprise content management and its involved technologies are discussed in Section 5.3.1. Thereby fundamentals of ECM as well as their benefits for a CKWS are described. Subsequently the principles of case management are presented as this approach features context-related access to information.

5.3.1 Fundamentals of ECM

ECM aims at the holistic management of content of all stripes in corporate environments, in other words from the capturing and creation of documents and content, via the management towards retention and deletion of content. The ECM industry association specifies the term of ECM as follows [92]:

> **Definition 5.4** ***Enterprise content management*** *is the strategies, methods and tools used to capture, manage, store, preserve, and deliver content and documents related to organizational processes. ECM tools and strategies allow the management of an organization's unstructured information, wherever that information exists.*

Definition 5.4 explicitly distinguishes content and documents as documents are supposed to refer to paper-based information like letters. Therefore the support of analogous, traditional documents is to be underlined. Generally companies expect from ECM initiatives to significantly reduce content access, deposit, transport and search times. In order to achieve these goals, the main functions which are to be established by an ECM initiative are [27]:

- *Capturing* of external documents and information (e.g. received customer letters).
- *Preparation* of captured content to be accessible in appropriate content types.
- *Deposition* and retention in suitable content types.
- *Provision* of adequate search possibilities.
- *Presentation*, printing and transfer of information to communication processes.
- *Distribution* of documents whenever required.
- *Management* of documents' data and processing flows.
- *Administration* of documents, their deposition as well as their access rights.
- *Backup* procedures for document repositories and related databases.

As a consequence an ECM system, intending to establish the desired support, has to combine a considerable number of different technologies and individual, subordinate information systems to cope with these versatile requirements. In general, such a holistic system is a vision or rather an objective [27]. Due to the broad range of requirements, there are many vendors in the ECM area providing products respectively systems specializing on certain core features of ECM, e.g. the capturing and preparation of received documents. Especially the availability of interfaces (APIs[5]) of and to existing systems in a corporate environment is a key success factor for an ECM system. Naturally some information systems mainly request content whereas others primarily host and provide content. In this context the integration into the user's mainly used applications is still one of the main issue current ECM systems share. To underline the benefits of an underlying ECM system for a CKWS, ECM core features and their relation to CKW are to be touched in the following.

5.3.1.1 Content Capture

In relation to ECM, information is generally separated into the categories *coded information* (CIN) and *non coded information* (NCIN). While the first represents information which is digitally available in appropriate shapes for further editing, the latter logically addresses all that information which is not processible in its current shapes. For instance, such information is paper-based documents, pictures, analogous audio and video files, etc. Crucially for an ECM system, there has to be functionality to capture and edit NCIN (in particular paper-based documents) in order to make them available in the company. Therefore hardware like scanners, cameras or specialized machines (e.g. digitizer) have to be integrated and appropriate OCR[6] software is requested to digitize, attribute and classify captured NCIN. Naturally the capturing processes are connected with high efforts and influenced by various parameters: the amount of information to be captured, the intended quality and data format, the desired time to capture documents (before or after the editing by users), the possibility to automatically attribute and classify documents (e.g. based on barcodes) or the need to manually review and edit documents.

The availability of captured NCIN in the context of their current project or case (i.e. CIs) can additionally foster the productivity of knowledge workers. If they can easily access priorly paper-based, detached content in appropriate shapes and in a context-related manner, they

[5] Application programming interface
[6] Optical character recognition

will not have to manually look for those documents in paper-based records and archives. Furthermore knowledge workers could link digitized NCIN to other content as well as they could access that content simultaneously. The principle technologies used in capturing processes are also interesting for knowledge workers intending to quickly add NCIN to a CI. As mobile devices feature considerable cameras and performance, NCIN like notes or images could be added ad-hoc to CIs today as well.

5.3.1.2 Content Retrieval

Based on a solid stock of available content (integrated as well as captured), an ECM system naturally needs to provide inquiry functionality to allow users to search and retrieve managed content. Therefore users usually have the choice between browsing the existing content repository, using a full-text search or searching certain content based on attributes (meta data) which were assigned to the content during the content capture processes. Obviously corresponding search masks need to be provided as well as powerful viewers in order to allow users to instantly inspect and manage inquired content. If an user wants to edit content more autonomously, ECM systems usually feature versioning concepts as well as check-in and check-out mechanisms (cf. [93]). Naturally the editing of content is closely connected to the integration of an ECM system into the applications users prefer to use. This is subject of Section 5.3.1.5.

Generally pre-configured content retrieval search masks could be connected to CTs enabling knowledge workers to dynamically search and add content during the run time of derived CIs. The better search possibilities a ECM system features, the faster knowledge workers can access content they are looking for. If content is attached with meaningful attributes (cf. Section 5.1.1.2) and the system provides smart repository structures, knowledge workers search processes can be significantly accelerated. Therefore a system logically has to establish indexes and caches to further improve search processes as well.

5.3.1.3 Content Integration

On the one hand side an ECM system logically needs to provide a broad range of interfaces to allow applications and systems to access managed content. On the other hand side existing information systems, which host and issue content, have to be integrated to manage content in an enterprise-wide, holistic manner. Unfortunately a lot of legacy systems might have to be integrated which requires the establishment of adapters and maybe tedious data conversion. In general the establishment of an enterprise-wide content management system depends on the availability of well-defined and well-kept adaptors and interfaces.

The integration of content into a CT obviously requires the prior integration of the corresponding data sources. In this context it has to be declared, for the avoidance of doubt, that adequate integration of data sources is a key success factor for the future success of a CKWS. Logically, the CKWS can thereby benefit from an ECM system featuring established connections to many existing corporate systems. Thus CKWS is similarly dependent on the availability of interfaces respectively established adapters.

5.3.1.4 Content Archiving

In many cases content has to be thoroughly archived or even conscientiously deleted to fulfill compliance rules and in particular legal requirements. Thereby archiving of content is naturally connected to legally recognized compression procedures as well as content type complying with recognized standards. ECM systems often comprise a dedicated archive server which can generally address the lifespan of content (short-term, mid-term and long-term) and which manages the storage of content accordingly.

In relation to CKW, the adequate storage of contents belonging to CIs is also necessary. Thereby the use cases can motivate several examples: content resulting from investigative work needs to be properly archived according to legal obligations. The collaboration of financial experts also addresses content which has to be archived for documentation and compliance regulations. A very sensitive area is represented by the medical example (cf. Chapter 2) as patient data are connected with strict legal obligations. So in general a CKWS and its compliance requirements (SR6, cf. Section 4.3.6) clearly benefit from technologies ensuring the proper archiving of sensitive content.

5.3.1.5 Content Distribution

Obviously an ECM system features many processes regarding the capturing, editing, revision, release or integration of content which can be standardized. Therefore most ECM systems either feature an integrated workflow component or they are closely aligned with a standalone BPMS. As a result the tremendous functionality of an ECM system, features can be orchestrated process-oriented as well as content can be integrated into the corporate business processes.

Logically a CKWS can profit from the integration of established processes addressing main areas like the capturing, editing and release of content. For instance, evidences in the shape of documents seized by investigators could thereby be captured and automatically allocated to the corresponding CI.

5.3.2 Case Management

Since a holistic ECM system is supposed to integrate a wide range of corporate data sources, it can logically offer a context-related access to content sharing a connection. Most ECM systems can provide an electronic folder comprising information for a certain purpose. Based on this generic principle, *case management systems* (CMS) offer an integrated access to content in relation to a *case*. Generally cases are slightly touched in Section 3.3.4 as CKW's different organisational shapes are introduced. The *Case Management Society of America* defines *case management* (CM) in the following way: *"case management is a collaborative process of assessment, planning, facilitation and advocacy for options and services to meet an individual's health needs through communication and available resources to promote quality cost-effective outcomes."* [94].

Hence the idea of CM and a case is well known in the medical domain, but also in law and administration. Considering the medical example (cf. Section 2.5.2), doctors can cooperate on the patient's case which presumably contains all relevant information concerning the patient's health and treatment history. Thus the patient's *case* file symbolizes a virtual unit which can provide a central point of information access as well as increased transparency. Thus a CMS aims for the systematic support of its users in processing one or more cases. Therefore cases can be generally supported by *case templates* which comprise pre-integrated content and a predefined course of action. Based on these templates users can add and change information to a case to proceed the case processing.

To further structure the cases' course of events, CMSs typically allow administrators to additionally configure case templates by adding further basic elements like predefined subcases, tasks, data structures, forms (to access the data) and actors including their roles (access rights). Naturally it is not possible to thoroughly examine all details of today's CMSs in the context of this thesis. But to generally examine the way how work is processed by the usage of cases, an academic foundation can be leveraged. For instance, the company *Pallas Athena*[7] offers a CMS called *BPMOne* which is directly based on the approach of *case handling* [84, 82]. Figure 5.4 depicts the recently mentioned basic elements of a case in a CMS as well as their relationships. The differentiation between complex and *normal* cases is required to ensure the possible nesting of cases.

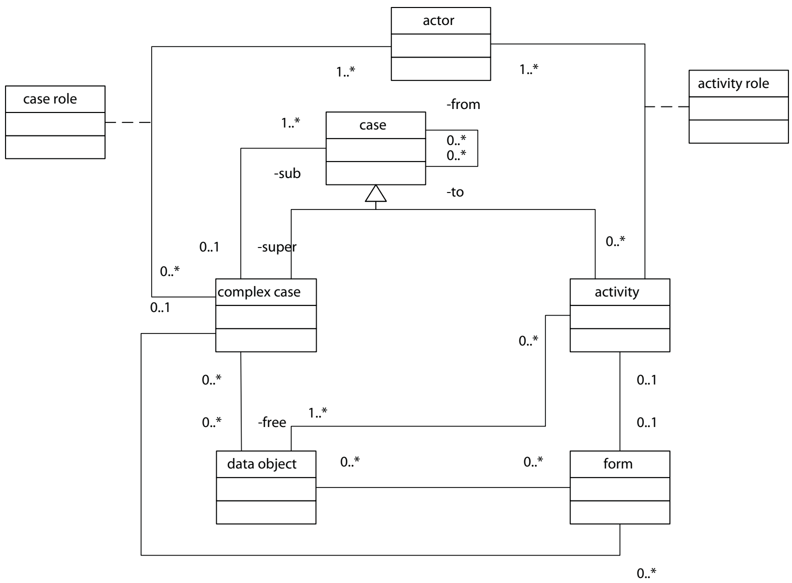

Figure 5.4: Case handling meta model, according to [82]

[7] `http://www.pallas-athena.com`

Although case handling is generally characterized as a data-driven approach, actually both activities and the input of data drive the progress of a case. Generally, there is a logical flow of activities which are explicitly represented through user forms including a number of input fields. These fields refer to atomic data elements which are either defined as free, restricted or mandatory. An activity is completed as soon as all mandatory data elements have been filled with a required value. Hence activities are automatically activated as soon as preceding activities have been successfully accomplished. While users respectively roles are generally assigned to activities, there can be authorized users who are allowed to skip and redo certain activities. The relationships between the mentioned case elements is illustrated by an example exposed in Figure 5.5. Thereby C1 represents the case itself, A1-A3 are included activities, D1-D5 symbolize contained data elements, F1-F3 depict available forms and R1-R2 are corresponding roles for users.

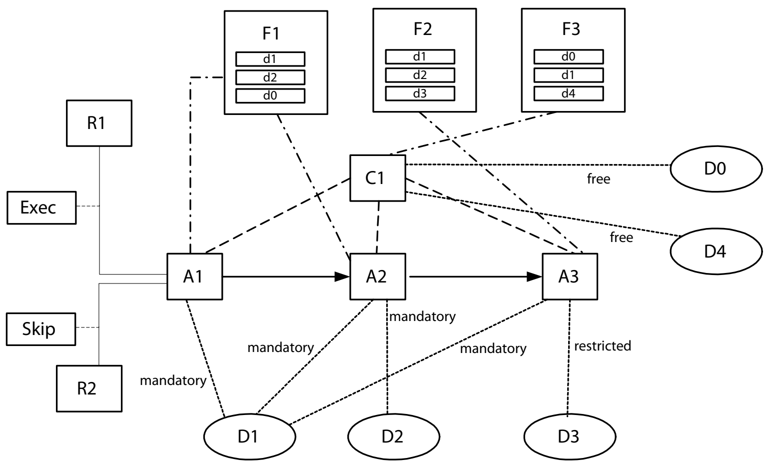

Figure 5.5: Case handling example, according to [82]

Evaluating Figure 5.5, the ordering of the activities is clearly visible as well as their connections to data elements and forms. A form can be used for multiple activities as long as they provide access to mandatory input fields. Thereby an user can accomplish for instance the activities A1 and A2 at once.

In summary CMSs can offer higher flexibility and an implicit focus on data in comparison to traditional BPMSs. Furthermore the provision of templates is principally aligned with the idea of a holistic support for collaborative knowledge workers (cf. Section 4.1). However the approach is still structured and the application of a CMS can be well considering if cases are frequently repeated and the processing is determined for the assurance of quality. However, the emergent character of CKW frequently coerces knowledge workers to change existing flows. Hence new data elements would have to be added during run time which can influence subsequent activities. Besides, current CMS lack of functionality for communication and agile coordination based on a case. Furthermore there is no appropriate awareness support and the inclusion, editing, sharing and linkage of gained, unstructured information is widely unprovided (cf. [95, 96]).

5.3.2.1 Adaptive Case Management

As of recently there are aspirations to better support knowledge work through the extension of existing CMS technologies. In this context, people refer to *Adaptive Case Management* (ACM) [47, 97]. Authors being associated with the WfMC[8] published a set of heterogeneous articles considering this topic in [97]. The common thrust is the goal to develop a rather generic case management system which provides case-related access to information combined with essential functionality to manage cases as well as to define objectives, deadlines and tasks. Moreover templates are supposed to provide predefined data structures and document templates to assist users instead to actively guide them. Generally the authors underlined knowledge workers' need for a support representing a trade-off between flexible processes and free collaboration.

However the authors missed to integrate an academical examination about how knowledge work respectively collaborative knowledge work is performed. As a result many articles significantly vary in their explanations what an advanced CMS has to provide in detail to substantially foster knowledge workers productivity. In relation the important requirements of awareness and communication (SR3 and SR4, cf. Section 4.3.3 and 4.3.4) are either not presented or only touched superficially. But the unimpeded exchange of information is crucially needed to finally empower knowledge workers to create new knowledge and

[8] Workflow Management Coalition, `http://www.wfmc.org/`

solutions for their companies (cf. the knowledge creating spiral, Section 2.2.2.1). In addition, this thesis does not equate knowledge workers' collaboration with the organizational shape of a case. Projects and spontaneous collaborations (e.g. for intermediate problem solving) are also common with CKW. For instance, knowledge workers certainly require different support for projects (methodologies, coordination) as for the accomplishment of cases. Nonetheless the contents of this thesis can be well appreciated in the context of ACM as this approach generally addresses the advancement of knowledge workers productivity as well.

5.4 Appraisal

Summarizing this section, various technologies have been presented which explicitly address specific requirements of a CKWS. Related to the original question, which technologies can already be leveraged for a CKWS, three of the presented ones shall be accentuated. Social network services provide a broad range of functionality, allowing knowledge workers to access needed awareness information as well as to communicate based on rich communication channels (requirements SR3 and SR4). The concept of constraint-based business process management could be leveraged to offer an agile coordination approach (requirements SR2) relying on predefined and fully supported activities. While undesired execution behavior is restricted (requirements SR6), the knowledge workers themselves could still widely choose and order the activities during the run time. However, for a proper usage in the context of a CKWS, this new approach has naturally to be further extended and qualified by future research. Finally, a CKWS could profit from an established ECM system (requirements SR1 and SR6) providing a high quantity of adaptors to existing systems (i.e. their content), sophisticated content management functionality as well as properly defined processes to digitize and integrate non-coded information.

6

Conclusion

In a global economy where the most valuable skill you can sell is your knowledge,
a good education is no longer just a pathway to opportunity – it is a prerequisite.

Barack Obama (*1961), incumbent president of the United States of America.

Finally this section provides a summary and conclusion of the thesis' results and an outlook on future research. Therefore Section 6.1 summarizes the valuable insights of the preceding sections and establishes a connection to the presented objectives in Section 1.2. Subsequently Section 6.2 lastly picks up on open research questions which have been arisen in the course of this thesis.

6.1 Summary

For an adequate résumé the problems collaborative knowledge workers currently face are briefly recapitulated. Today's knowledge workers collaboratively perform knowledge work widely individually without an appropriate context-related support, which can centrally provide contextual information or the current state of progress. While coping with dynamic and challenging situations knowledge workers have to autonomously gather and manage information of all types as well as they have to individually take care of communication, coordination and awareness. Thus elaborated solutions and knowledge often gets lost and is not utilized for future undertakings as information is inherently distributed, misses its important contextual linkage and is not preserved sustainably.

Hence Section 1.2 presents two interrelated objectives of this thesis, directly addressing the mentioned issues: Concisely, *objective I* is to examine the characteristics of an information system which aims to holistically support collaborative knowledge workers. To approach such an information system the intermediate *objective II* has to be achieved before – the thorough examination of knowledge work and its involved workers.

The detailed examination of knowledge work clearly underlined, that knowledge work explicitly addresses novel and complex processes and work results in comparison to intellectual work. This result clearly qualifies existing assumptions generally equating the performance of intellectual work with the accomplishment of knowledge work. In order to collaboratively handle problems and situations featuring high dynamics and various influencing factors, knowledge workers mainly rely on their high level of education, experience and expertise. As a further result collaborative knowledge work is characterized by a common goal orientation, the emergence of work processes as well as a common, growing knowledge base. Apart from these fundamental characteristics CKW use cases can be described and differentiated along dimensions which have been established by the thesis' case study. Based on these results CKW can be better understood and lastly supported by a targeted information system (i.e. a CKWS).

Drawing upon the preparatory work the thesis' second part has its focus on the requirements a CKWS has to satisfy as well as a set of possible technologies which can be leveraged to establish such a system. For this purpose a conceptional lifecycle approach is presented which allows knowledge workers to reuse records of elaborated work in order to significantly reduce the processing times of current endeavors. In order to ensure knowledge workers' collaboration in a CKWS, general and system-specific requirements are derived from the preceding CKW use case study. Especially the various system-specific requirements underline the broad range of support a CKWS has to offer in a well-integrated way. Generally it can be summarized that a central, context-related information access combined with multifaceted communication and agile coordination capabilities is the key requirement for a CKWS. Thereby the gap between the social and technological environments of the knowledge workers can be likely reduced. This insight is also confirmed by the evaluation of the technologies: for instance, social network services offer multiple potential capabilities to improve communication and awareness between collaborative knowledge workers and ECM technologies can provide established integration concepts (adapters, capture processes) regarding today's still widely used paper-based documents.

As a conclusion of the thesis the holistic and process-oriented support for collaborative knowledge workers is a challenge in the literal sense. Although there is broad range of available technologies targeting single aspects of a CKWS, the integration of those into a utilizable CKWS implies high efforts and distinguished concepts for the technologies' interplay. However this conceptional work can be leveraged as a vision to gradually extend and interconnect concepts and technologies towards an intended holistic support according to the CKWL. Furthermore, due to the importance of the subject of knowledge work, the public and scientific awareness has to be gradually increased and future efforts are obviously needed in order to finally improve the productivity of today's economically important workers – the knowledge workers.

6.2 Outlook

As this thesis' focus is on a conceptional level, various topics and involved research fields have been principally touched. Of course, there is a broad range of possible topics, requirements or available technologies which have not been considered so far. However, due to knowledge work's implicit interdisciplinary character (cf. Section 2.1), future research in this area will likely benefit from cooperation between researchers belong to the different domains. Thereby researchers are supposed to intensify studies considering the way knowledge workers collaboratively perform knowledge work (e.g. field studies) as well as they can address open issues for an intended information system, which have been arisen during the course of this work. Only a short selection of those issues are exposed in the following list:

- Based on the CKWL a *transparent methodology* has to handle the support complexity and to establish a modeling language to adequately define CTs. While content integration has to be especially considered, the degree of support considering the requirement categories SR2-SR6 has to be adjustable (cf. Section 4.3). Furthermore knowledge workers need to be enabled to adaptively and easily change the CIs during run time.

- The *detection of the current state* of a CI is required for a rather synchronized support of collaborative knowledge workers. Although CTs are *merely* supposed to be collaboration frameworks, an approximate state can be leveraged to increase the process-related support as well as to ensure proper awareness and compliance support. Naturally this topic is related to a detailed methodology.
- The *usage of collaboration records* logically implies the questions what can be leveraged and which parts have to be omitted due compliance requirements, like privacy issues. Naturally the access to such repositories has to be closely regulated and advanced concepts are requested in this area.
- The *dynamic integration of content* into corresponding CIs logically requires sophisticated concepts to gather, compile and edit data to be easily usable by the involved knowledge workers.
- Finally, a *CKWS's usability* is a key success factor for a successful acceptance of the system by knowledge workers. Different technologies have to be well integrated and compiled under the surface of appealing and state-of-the-art user interfaces. However user interfaces have to be highly customizable as domain-specific preferences might have to be considered for certain CTs.

While the preceding list is only a selection of five specific issues, the conceptional idea of a CKWS generally implies versatile detailed future work on this topic. Therefore this thesis has set a starting point to increase the understanding of knowledge work in computer science as well as to approach a holistic support for collaborative knowledge workers.

List of Figures

Bibliography

[1] M. Weske, *Business Process Management: Concepts, Languages, Architectures*. Berlin: Springer, 2007.

[2] F. Nordsieck, *Die schaubildliche Erfassung und Untersuchung der Betriebsorganisation*. Stuttgart: C. E. Poeschel, 1932.

[3] M. Hammer and J. Champy, *Reengineering the Corporation: A Manifesto for Business Revolution*. New York: HarperBusiness Essentials, 2003.

[4] W. M. P. v. d. Aalst, A. H. M. t. Hofstede, and M. Weske, "Business Process Management: A Survey," in *Proceedings of the 1st International Conference on Business Process Management, volume 2678 of LNCS*. Springer, 2003, pp. 1–12.

[5] M. Pfiffner and P. Stadelmann, *Wissen wirksam machen: Wie Kopfarbeiter produktiv werden*. Bern: Haupt Verlag, 1998.

[6] P. F. Drucker, *Management Challenges for the 21st Century*. Oxford: Elsevier Science & Technology, 2007.

[7] T. H. Davenport, *Thinking for a Living: How to Get Better Performance and Results from Knowledge Workers*. Harvard Business School Press, 2005.

[8] H. Wilke, "Organisierte Wissensarbeit," in *Zeitschrift für Soziologie*, 1998, vol. 27, pp. 161–177.

[9] D. Dean and C. Webb, "Recovering from information overload," in *The McKinsey Quarterly January*, 2011. [Online]. Available: https://www.mckinseyquarterly.com/Recovering_from_information_overload_2735 [Accessed: 25-05-2011]

[10] P. F. Drucker, *Landmarks of Tomorrow: A Report on the New "Post-Modern" World*. New Brunswick, N.J., U.S.A: Transaction Publishers, 1996.

[11] ——, “The New Productivity Challenge,” *Harvard Business Review*, vol. 69, no. 6, pp. 69–79.

[12] F. Machlup, *The Production and Distribution of Knowledge in the United States*. Princeton: Princeton University Press, 1962.

[13] D. Bell, *The Coming of Post-Industrial Society: A Venture in Social Forecasting*. New York: Basic Books, 1976.

[14] A. Toffler, *The Third Wave*. New York: Bantam Books, 1980.

[15] P. H. Carstensen and K. Schmidt, “Computer Supported Cooperative Work: New Challenges to Systems Design,” in *Handbook of Human Factors*, In K. Itoh, Ed., 1999, pp. 619–636.

[16] C. A. Ellis, S. J. Gibbs, and G. Rein, “Groupware: some issues and experiences,” *Communications of the ACM*, vol. 34, no. 1, pp. 39–58, 1991.

[17] J. Grudin, “CSCW: the convergence of two development contexts,” in *Proceedings of the SIGCHI conference on Human factors in computing systems: Reaching through technology*, ser. CHI ’91. ACM, 1991, pp. 91–97.

[18] T. Gross and M. Koch, *Computer-Supported Cooperative Work*. München: Oldenbourg Wissenschaftsverlag, 2007.

[19] A. Aamodt and M. Nygard, “Different roles and mutual dependencies of data, information, and knowledge - an AI perspective on their integration,” *Data and Knowledge Engineering*, vol. 16, no. 3, pp. 191–222, 1995.

[20] T. H. Davenport and L. Prusak, *Working Knowledge: How Organizations Manage What They Know*. Boston: Harvard Business School Press, 2000.

[21] T. Goesmann, “Ein Ansatz zur Unterstützung wissensintensiver Prozesse durch Workflow-Management-Systeme,” Ph.D. dissertation, Technische Universität, Berlin, 2002.

[22] I. Nonaka and H. Takeuchi, *The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation*. New York: Oxford University Press, 1995.

[23] M. Weggeman, *Wissensmanagement: Der richtige Umgang mit der wichtigsten Ressource des Unternehmens*. Bonn: MITP-Verlag, 1999.

[24] G. Hube, "Beitrag zur Beschreibung und Analyse von Wissensarbeit," Ph.D. dissertation, Universität Stuttgart, Stuttgart, 2005.

[25] M. Polanyi, *Tacit Dimension*. Gloucester, Mass.: Peter Smith Publisher Inc, 1983.

[26] H. Takeuchi and I. Nonaka, *Hitotsubashi on Knowledge Management*. Singapore: John Wiley & Sons (Asia), 2004.

[27] J. Gulbins, M. Seyfried, and H. Strack-Zimmermann, *Dokumenten-Management*, 3rd ed. Berlin and Heidelberg: Springer, 2002.

[28] A. Toffler, *Future Shock*. New York: Bantam Books, 1990.

[29] W. Hacker, *Allgemeine Arbeitspsychologie: Psychische Regulation von Wissens-, Denk- und körperlicher Arbeit*, 2nd ed. Bern: Huber, 2005.

[30] M. Resch, *Die Handlungsregulation geistiger Arbeit: Bestimmung u. Analyse geistiger Arbeitstätigkeiten in d. industriellen Produktion*. Bern: Huber, 1988.

[31] P. F. Drucker, *Management. An abridged and revised version of Management: Tasks, Responsibilities, Practices.* Oxford: Butterworth-Heinemann, 1991.

[32] J. W. Cortada, Ed., *Rise of the Knowledge Worker*. Boston: Butterworth-Heinemann, 1998.

[33] J. W. Cortada, *21st Century Business: Managing and Working in the New Digital Economy*. Upper Saddle River, NJ: Financial Times/Prentice Hall, 2000.

[34] B. DeFillippi, M. B. Arthur, and V. J. Lindsay, *Knowledge at Work: Creative Collaboration in the Global Economy*. Malden, MA: Blackwell Pub., 2006.

[35] K. D. Swenson, "The Nature of Knowledge Work," in *Mastering the Unpredictable*, K. D. Swenson, Ed. Meghan-Kiffer-Press, 2010, pp. 5–28.

[36] W. Dostal and A. Reinberg, "Arbeitslandschaft 2010 * Teil 2: Ungebrochener Trend in die Wissensgesellschaft. Entwicklung der Tätigkeiten und Qualifikationen." *IAB-Kurzberich*, no. 10, pp. 1–6, 1999.

[37] W. Dostal, "Beschäftigung und Berufsbildung aus Sicht des Arbeitsmarktes," *Informationen für die Beratungs- und Vermittlungsdienste der Bundesanstalt für Arbeit*, no. 12, pp. 1479–1496, 2003.

[38] B. C. Johnson, J. M. Manyika, and L. A. Yee, "The next revolution in interactions," *The McKinsey Quarterly*, no. 4, pp. 21–33, 2005.

[39] I. Brinkley and N. Lee. (2006) The knowledge economy in Europe. [Online]. Available: http://www.theworkfoundation.com/assets/docs/publications/80_Knowledge%20Economy%20EU%20Spring%20Council.pdf [Accessed: 07-06-2011]

[40] S. C. Beardsley, B. C. Johnson, and J. Manyika, "Competitve advantage from better interactions," *The McKinsey Quarterly*, no. 2, pp. 52–63, 2006.

[41] L. L. Bryan and C. Joyce, "The 21st-century organization," *The McKinsey Quarterly*, no. 3, pp. 25–33, 2005.

[42] S. L. Kogan and M. J. Muller, "Ethnographic study of collaborative knowledge work," *IBM Systems Journal*, vol. 45, no. 4, pp. 759–771, 2006.

[43] T. H. Davenport, "Rethinking knowledge work: A strategic approach," in *The McKinsey Quarterly February*, 2011. [Online]. Available: https://www.mckinseyquarterly.com/Rethinking_knowledge_work_A_strategic_approach_2739 [Accessed: 27-04-2011]

[44] F. Bentele, "Emergent Workflow," Ph.D. dissertation, Universität Ulm, 2005.

[45] Verein Deutscher Ingenieure e.V. (2004) Design methodology for mechatronic systems. [Online]. Available: http://www.vdi.de/8089.0.html?&tx_vdirili_pi2[showUID]=89883 [Accessed: 12.09.2011]

[46] C. A. Sennewald and J. K. Tsukayama, *The Process of Investigation: Concepts and Strategies for Investigators in the Private Sector*, 3rd ed. Burlington, MA: Butterworth-Heinemann, 2006.

[47] C. Le Clair and C. Moore. (2009) Dynamic Case Management: An Old Idea Catches New Fire. [Online]. Available: http://www.emc.com/collateral/analyst-reports/csg8619-forrester-dynamic-case-management-ar.pdf [Accessed: 11-03-2011]

[48] T. O. Davenport, *Human Capital: What It Is and Why People Invest It*, 1st ed. San Francisco: Jossey-Bass, 1999.

[49] C. W. Holsapple and K. Jones, "Exploring primary activities of the knowledge chain," *Knowledge and Process Management*, vol. 11, no. 3, pp. 155–174, 2004.

[50] W. Reinhardt, B. Schmidt, P. Sloep, and H. Drachsler, "Knowledge Worker Roles and Actions-Results of Two Empirical Studies," *Knowledge and Process Management*, vol. 18, no. 3, pp. 150–174, 2011.

[51] Merriam-Webster. Dictionary. [Online]. Available: http://www.merriam-webster.com/dictionary [Accessed: 09-08-2011]

[52] T. Brown, *Change by Design: How Design Thinking Transforms Organizations and Inspires Innovation*, 1st ed. New York: Harper Business, 2009.

[53] Project Management Institute, *A Guide to the Project Management Body of Knowledge*. Newtown Square, Penn: PMI Project Management Institute, 2000.

[54] S. Ruppenthal, "Vielfalt und Verbreitung berufsbedingter räumlicher Mobilität im europäischen Vergleich," *Bevölkerungsforschung Aktuell*, vol. 31, no. 2, pp. 2–7, 2010.

[55] D. J. Mayhew, *The Usability Engineering Lifecycle: A Practitioner's Handbook for User Interface Design*. San Francisco, Calif: Morgan Kaufmann Publishers, 1999.

[56] B. Weber, S. Rinderle-Ma, and M. Reichert, "Change patterns and change support features in process-aware information systems," in *Proceedings of the 19th international conference on Advanced information systems engineering*, ser. CAiSE'07. Springer-Verlag, 2007, pp. 574–588.

[57] W. A. Ruh, W. J. Brown, and F. X. Maginnis, *Enterprise Application Integration: How to Successfully Plan for EAI (A Wiley tech brief)*. New York: Wiley, 2001.

[58] T. W. Malone and K. Crowston, "What is coordination theory and how can it help design cooperative work systems?" in *Proceedings of the 1990 ACM conference on Computer-supported cooperative work - CSCW '90*. ACM Press, 1990, pp. 357–370.

[59] G. T. Doran, "There's a S.M.A.R.T. way to write management's goals and objectives," in *Management Review Issue 11(AMA FORUM)*, 1981, vol. 70, pp. 35–36.

[60] R. Pichler, *Scrum - Agiles Projektmanagement erfolgreich einsetzen*. Heidelberg: dpunkt-Verl., 2009.

[61] T. H. Davenport, S. Jarvenpaa, and M. Beers. (1995) Improving Knowledge Work Processes. [Online]. Available: http://www.providersedge.com/docs/km_articles/improving_knowledge_work_processes.pdf [Accessed: 30-05-2011]

[62] M. Koch and A. Richter, *Enterprise 2.0: Planung, Einführung und erfolgreicher Einsatz von Social-Software in Unternehmen*, 2nd ed. München: Oldenbourg, 2009.

[63] C. Gutwin and S. Greenberg, "Support for Group Awareness in Real-time Desktop Conferences," in *Proceedings of The Second New Zealand Computer Science Research Students' Conference*, 1995, pp. 18–21.

[64] ——, "Workspace Awareness for Groupware," in *Conference companion on Human factors in computing systems: common ground*. ACM, 1996, pp. 208–209.

[65] W. M. P. v. d. Aalst, *Process Mining: Discovery, Conformance and Enhancement of Business Processes*. New York: Springer, 2011.

[66] M. Bächle, "Social Software," *Informatik-Spektrum*, vol. 29, no. 2, pp. 121–124, 2006.

[67] B. Leuf and W. Cunningham. (2002) Wiki: What Is Wiki. [Online]. Available: http://www.wiki.org/wiki.cgi?WhatIsWiki [Accessed: 14-09-2011]

[68] Etherpad. [Online]. Available: http://etherpad.org/ [Accessed: 15-09-2011]

[69] DBpedia. [Online]. Available: http://www.dbpedia.org/ [Accessed: 14-09-2011]

[70] S. A. Golder, "Usage patterns of collaborative tagging systems," *Journal of Information Science*, vol. 32, no. 2, pp. 198–208, 2006.

[71] Delicious. [Online]. Available: http://delicious.com/ [Accessed: 16-09-2011]

[72] digg. [Online]. Available: http://www.digg.com [Accessed: 16-09-2011]

[73] D. M. Boyd and N. B. Ellison, "Social Network Sites: Definition, History, and Scholarship," *Journal of Computer-Mediated Communication*, vol. 13, no. 1, pp. 210–230, 2007.

[74] SNA Demo. [Online]. Available: http://sna-demo.ondemand.com [Accessed: 21-09-2011]

[75] Facebook Videocalling. [Online]. Available: http://www.facebook.com/videocalling/ [Accessed: 20-12-2011]

[76] Google Plus Hangout. [Online]. Available: http://www.google.com/tools/dlpage/res/talkvideo/hangouts/ [Accessed: 20-12-2011]

[77] G. Alonso, D. Agrawal, A. E. Abbadi, and C. Mohan, "Functionality and Limitations of Current Workflow Management Systems," *IEEE Expert*, vol. 12, no. 5, 1997.

[78] M. Reichert and P. Dadam, "ADEPT flex – Supporting Dynamic Changes of Workflows Without Losing Control," *Journal of Intelligent Information Systems*, vol. 10, no. 2, pp. 93–129, 1998.

[79] B. Weber, S. Sadiq, and M. Reichert, "Beyond Rigidity - Dynamic Process Lifecycle Support: A Survey on Dynamic Changes in Process-aware Information Systems," *Computer Science - Research and Development*, vol. 23, no. 2, pp. 47–65, 2009.

[80] M. Pesic, M. H. Schonenberg, N. Sidorova, and W. M. P. v. d. Aalst, "Constraint-based workflow models: change made easy," in *Proceedings of the OTM 2007*, 2007, pp. 77–94.

[81] H. Schonenberg, R. Mans, N. Russell, N. Mulyar, and W. M. P. v. d. Aalst, "Towards a Taxonomy of Process Flexibility," in *Proceedings of the Forum at the CAiSE'08 Conference*, Z. Bellahsène, C. Woo, E. Hunt, X. Franch, and R. Coletta, Eds., 2008, pp. 81–84.

[82] W. M. P. v. d. Aalst, M. Weske, and D. Grünbauer, "Case handling: a new paradigm for business process support," *Data & Knowledge Engineering*, vol. 53, no. 2, pp. 129–162, 2005.

[83] V. Künzle and M. Reichert, "Striving for Object-aware Process Support: How Existing Approaches Fit Together," in *1st Int'l Symposium on Data-driven Process Discovery and Analysis (SIMPDA'11)*, 2011.

[84] H. A. Reijers, J. H. M. Righter, and W. M. v. d. Aalst, "The Case Handling Case," *International Journal of Cooperative Information Systems*, vol. Vol. 12, no. 3, pp. 365–391, 2003.

[85] V. Künzle, B. Weber, and M. Reichert, "Object-aware Business Processes: Fundamental Requirements and their Support in Existing Approaches," *International Journal of Information System Modeling and Design (IJISMD)*, vol. 2, no. 2, pp. 19–46, 2011.

[86] M. Pesic, "Constraint-Based Workflow Management Systems: Shifting Control to Users," Ph.D. dissertation, Eindhoven University of Technology, 2008.

[87] W. M. P. v. d. Aalst and M. Pesic, “DecSerFlow: Towards a Truly Declarative Service Flow Language,” in *The Role of Business Processes in Service Oriented Architectures, Dagstuhl Seminar Proceedings 06291*, F. Leymann, W. Reisig, S. R. Thatte, and W. M. v. d. Aalst, Eds., 2006.

[88] D. C. Luckham, *The Power of Events: An Introduction to Complex Event Processing in Distributed Enterprise Systems*. Boston: Addison-Wesley, 2002.

[89] M. Schacher and P. Grässle, *Agile Unternehmen durch Business Rules*. Berlin, Heidelberg, New York: Springer, 2006.

[90] S. T. H. Boley and G. Wagner, “Design Rationale of RuleML: A Markup Language for Semantic Web Rules,” in *Proc. Semantic Web Working Symposium*, I. F. Cruz, S. Decker, J. Euzenat, and D. L. McGuinness, Eds., 2001, pp. 381–402.

[91] J. Taylor and N. Raden, *Smart Enough Systems: How to Deliver Competitive Advantage by Automating Hidden Decisions*. Upper Saddle River, NJ: Prentice Hall, 2007.

[92] Association for Information and Image Management. What is Enterprise Content Management? [Online]. Available: http://www.aiim.org/What-is-ECM-Enterprise-Content-Management [Accessed: 17-03-2011]

[93] H.-P. Fröschle and S. Reich, *Enterprise Content Management*. Heidelberg: dpunkt-Verlag, 2007.

[94] Case Management Society of America. (22-08-2011) What is a Case Manager? [Online]. Available: http://www.cmsa.org/Home/CMSA/WhatisaCaseManager/tabid/224/Default.aspx [Accessed: 22-08-2011]

[95] S. Kemsley. Column 2: Pega Case Management. [Online]. Available: http://www.column2.com/2011/02/pega-case-management/ [Accessed: 28-02-2011]

[96] ——. Column 2 : IBM Case Manager In Depth. [Online]. Available: http://www.column2.com/2010/11/ibm-case-manager-in-depth/ [Accessed: 24-07-2011]

[97] K. D. Swenson, Ed., *Mastering the Unpredictable: How Adaptive Case Management Will Revolutionize the Way That Knowledge Workers Get Things Done*. Meghan-Kiffer-Press, 2010.

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Affidavit

I herewith declare in lieu of oath that I have composed this thesis without any inadmissible help of a third party and without the use of aids other than those listed. The data and concepts that have been taken directly or indirectly from other sources have been acknowledged and referenced.

This thesis has not been submitted, wholly or substantially, neither in this country nor abroad for another degree at any university or institute.

Ulm, January 11th, 2012   ....

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