A Survey on Modelling Knowledge-intensive Business Processes from the Perspective of Knowledge Management

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Abstract: Existing modelling approaches for knowledge-intensive business processes try to match the character of these processes by specific modelling concepts and methods. The approaches differ significantly depending on the focus of modelling. DeCo and KIPN for example recommend to be less strict on control flow orientation. KMDL allows for modelling down to the level of individuals. SBPM and KPR as well emphasize a detailed model and additionally underline the importance of distributed modelling. GPO-WM in contrast suggests avoiding too much details. However, which approach or what level of abstraction is now suitable for which modelling task from the perspective of knowledge management? Can the models be reused for other tasks? The search for the "right" way for modelling knowledge-intensive processes and issues derived therefrom are in the focus of discussion.

1 INTRODUCTION

Nowadays, knowledge is recognized as an important enterprise resource. Thus, knowledge management is derived as a management task. Here, business process oriented knowledge management aims at the ways of dealing with knowledge and requirements for knowledge and knowledge activities (use, production, and transfer of knowledge) in business processes. Remus puts knowledge-intensive business processes in the focus of a process-oriented knowledge management (Remus, 2002, p.108). Here lies the biggest success potential for knowledge management. Table 2 summarizes the typical characteristics of knowledge-intensive processes. They are commonly found in knowledge-intensive domains and are characterized by a high degree of complexity. Control flow varies widely, so that a high coordination and communication effort is required. Knowledge-intensive processes are often poorly structured, show a high number of participants (experts), and are difficult to plan. Due to their nature, it is difficult to reassign tasks to different individuals (Remus, 2002, pp. 104-117). Heisig sees as the most relevant criterion of knowledge-intensive processes that required knowledge can be planned ahead only in a limited manner (Heisig, 2002).

In order to model the knowledge support of processes, it is no longer sufficient to restrict the process to a sequence of activities, events and decisions consequently. Rather, it is necessary that important components from the perspective of knowledge management can be presented and that the modelling methodology fits to the special characteristics of these processes.

Considered to model components are:

1. Knowledge activities
   a. Knowledge creation and knowledge use (Allweyer, 1998, pp. 165)
   b. Knowledge transfer
2. Knowledge resources
   a. Knowledge carriers (Allweyer, 1998, pp. 165)
   b. Knowledge sources
3. Knowledge Structure Conditions
   a. ICT-involvement, the tech-nologies used (Scheer, 1998, pp.63-65)
   b. Organisational requirements and corporate culture (Lehner et al., 2007)

On the same hand, the high complexity and variability of knowledge-intensive processes has to be considered by the modelling methodology.

In business processes, activities are performed in

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a logical sequence by individuals who act in roles. For the successful completion of knowledge-intensive tasks the individuals must satisfy their need for knowledge with the help of knowledge activities. Here, they interact more or less efficiently through various media with other people and IT systems. During these interactions new knowledge is generated constantly. However, it can only partly be preserved. In order to transfer these processes into a model, a structured approach is needed, which selects a proper level of detail. Since good models represent an appropriate part of the real world, it is possible to draw an analysis on how processes can be improved in the real world based on these models. Furthermore, the modelling provides the advantage that knowledge about business processes can be documented and shared. In the following section, state-of-the-art methods to collect and analyze knowledge-intensive business processes are presented. They should ensure a correct model of implicit and explict knowledge. The third section then provides an evaluation of the presented approaches in relation to the initially formulated modelling requirements. The final section summarizes the found open challenges for modelling knowledge-intensive processes.

2 APPROACHES TO MODELLING AND ANALYSIS OF KNOWLEDGE-INTENSIVE BUSINESS PROCESSES

In the literature there is a variety of approaches to modelling knowledge-intensive processes and modelling of knowledge management aspects in process models.

This section discusses a selection. A part of approaches has been selected based on an analysis of the citation (> 50 citations in Google Scholar). Thus a high scientific impact can be assumed. Additionally, DeCo and KIPN (> 10 citations) have been selected, which have been published more recently. They do not have a comparable citation count. However, we assume that the limited timeframe is the major reason for that. Thus we discuss well established approaches (>50 citations) and current trends and ideas (DeCo and KIPN).

2.1 Knowledge Modelling and Description Language

The Knowledge Modelling and Description Language (KMDL) is a method for modelling knowledge-intensive business processes that is still

Table 1: Attributes of knowledge-intensive processes according to Remus (2002).

Attribute class	Typical attribute values of knowledge intensive processes
Process independent attributes (knowledge intensive domain)	• often decentralized networking organization showing a goal oriented support of knowledge transfer, e.g. by incentives • Knowledge intensive domain (key technologies) • Complex relations between processes
Attributes concerning the process (variablility)	• Complex processes having many dependent single activities, actors that work in interdisciplinary teams • Many exceptions, unpredictable control flow and results • Poorly structured, only ex-post modelling possible • High coordination and communication effort between the actors, needs knowledge from different domains • Generating knowledge-intensive products and services • Only imprecise controlling possible, often qualitative goals • Low number of process instances having long running times • Process case driven, no standard process
Attributes concerning tasks (poor transferability)	• Productivity of knowledge work usually not measurable • Long learning and and training periods necessary • Chaotic workplace • Tasks are communication oriented, require a lot of information, case driven • Typical tasks are: decision making, problem solving, analysis and evaluation, controlling and management
Attributes concerning actors (experts)	• Highly autonomous actors • Unstructured and individualized rules and routines • High competency, learning aptitude, creativity and innovation required
Attributes concerning resources (complex resources)	• Wide use of knowledge management instruments, informal knowledge transfer • Knowledge often hardly accessible and highly depending on the context • High amount of handled knowledge, cost intensive knowledge acquisition.

under active development. (Gronau, 2009, pp. 76-79) (KMDL, 2014).

KMDL is distinct from other approaches due to its person or individual related knowledge modelling. Here, the method provides an explicit modelling of individual knowledge conversions as introduced by Nonaka and Takeuchi (1995). In addition, the method provides various analysis views and comparative patterns for analysis.

The KMDL method is based on a nine-phase process model. The active participation of the project partner is required for successful knowledge management projects. First, in phase 0 the organizational framework is set. In Phase 1, the definition of the intended objectives of the project follows. Then, in Phase 2, the processes of the project partner are iteratively registered, refined and validated. This is the base for deriving knowledge intensive processes in phase 3. In Phase 4 these knowledge-intensive processes are iteratively modelled and sequentially analysed for possible improvements in phase 5. Specifically, the focus lies on finding weaknesses in order to derive suggestions for improvement from them. Then they are classified and evaluated, and finally there is an assessment of the potential for improvement. In the following 6th phase to-be concept is developed with the partners, which will be implemented in phase 7. In the final phase 8 the whole process will be evaluated together with the project partner. (Gronau, 2009, pp.75)

KMDL defines three views for the different requirements of modelling knowledge-intensive processes. The process view shows the business processes at an abstract level. Here, individual activities are displayed in their logical order in conjunction with the involved resources. Activities are broken down to knowledge transformations (e.g. socialization) in the activity view. The activity view is also the basis for the communication view, which describes how individual knowledge transformations are performed in conversations. Conversations are characterized by location (the same location / different location) and time (synchronous / asynchronous). (Pogorzelska, 2009, pp. 21-45)

KMDL analysis is based on these models. In the first analysis the frequencies of knowledge objects and conversation types (e.g. socialization) are counted and evaluated accordingly. A high number of socialization activities may for example indicate that too little knowledge is explicated. A recurring knowledge resource or a person who is involved in many activities in contrast may point to a possible bottleneck or a key function. Thus, knowledge needs are matched with knowledge services, and there is an assessment of the models regarding specific patterns. There are concrete improvement actions indicated for each pattern. (Pogorzelska, 2009, pp. 49-79)

KMDL provides a holistic approach to modelling and improvement of knowledge-intensive processes. For modelling with KMDL, the tool K-Modeler (K-Modeler, 2014) is available. The method has been criticized for the extra effort that is induced by the collection of the individual knowledge transformations. It can only be justified by better coverage of improvement measures for knowledge management (Krallmann et al., p 417). Thus, this method is very time consuming and the results strongly depend on the trust of the interviewees and the skills of the interviewer (Müller et al., 2012, pp.362).

2.2 Knowledge Process Reengineering

The Knowledge Process Reengineering (KPR) approach (Allweyer, 1998, pp.163- 168) is a seven-step approach to improve the handling of the resource "knowledge". In particular, the approach aims at effective knowledge sharing, good documentation and easy access to knowledge. KPR was developed for use in enterprises and can be supported by ARIS models. The individual phases, starting with the strategic knowledge planning, going on about the actual analysis and target conception, to implementation, run linearly in KPR. Re-entering a completed phase is not considered. Instead, the approach provides an ongoing testing and improvement process in the final phase.

KPR starts with strategic knowledge planning. Here is determined how knowledge management can support the company's strategic objectives. Models which relate the core business processes to the strategic business objectives help in this phase. Subsequently, an as-is modelling of knowledge usage and transformation is performed. The KPR approach uses EPC for process description due to its tight coupling to ARIS. Then knowledge carriers, knowledge categories and knowledge needs must be captured in knowledge structure diagrams, knowledge maps and additional information in the EPC diagrams. (Allweyer, 1998, pp.164-166)

Once the as-is situation has been modelled, its analysis begins. Here, critical knowledge monopolies, unsatisfied knowledge needs, inadequate knowledge profiles of employees etc. are revealed. The following development of a to-be concept for knowledge handling provides measures to solve the previously found issues. This is done for

example, by target knowledge profiles for employees or changes in business processes. After the to-be concept is set, realisation concepts for the organisation and the ICT are developed. The realization concept regarding the organisation includes staff trainings regarding new processes and new IT systems. The ICT realization concept includes the selection of appropriate IT solutions, the definition of content structures and system integration.

After implementing the to-be concept by the developed realization concepts, a phase of testing and possibly improving starts. (Allweyer, 1998, pp.166-168)

KPR thus offers an approach, which aims to anchor technologies of knowledge management in the working procedures of employees. The strong dependence on the underlying ARIS architecture, the requirement to model all the knowledge of a company, and the lack of a detailed description of single method steps are critical issues of KPR. In consequence, KPR is only a specific process model for the integration of IT in knowledge-intensive business processes.

2.3 PROMOTE

Hinkelmann et al., (2002, pp. 65-68) presented with process-oriented methods and tools for knowledge management (PROMOTE) a technology-independent method for the management of functional and process knowledge. It is an evolution of the business process management system framework (BPMS) (Karagiannis, 1995) and supplements this by the software tool PROMOTE (BOC, 2014). PROMOTE focuses on the identification, modelling and integration of processes that require and generate knowledge. The software supports the processing of knowledge-intensive activities by knowledge processes can be activated context-specific. Furthermore, it provides knowledge maps and topic maps as configurable knowledge management tools and. Finally, PROMOTE provides management capabilities for knowledge flows and a model-based indexing of documents with process- and role-specific access rights.

As a prerequisite for the approach, the following assumptions are made:

1. Knowledge processes can be modelled the same way as business processes
2. Activities in business processes use knowledge.

Base for the use of PROMOTE the method steps which provide high degree of freedom. Depending on the context the order of these steps and the final results may vary. The general goal is a support of knowledge flows between knowledge-intensive business processes. This knowledge flows can occur within a business process, across business processes, within a project, and even across projects. In addition, external knowledge inflows by training, internet research, etc. are possible. (Hinkelmann et al., 2002, pp. 68-71)

Realization is done in the five phases “Aware Enterprise Knowledge”, “Discover Knowledge Process”, “Modelling Knowledge Processes and Organisational Memory”, “Making Knowledge Processes and Organisational Memory operational” and “Evaluate Enterprise Knowledge”. In the first phase corporate goals are adjusted and strategically determined. These are for example products, services, financial requirements and the development of core competencies. The aim is an alignment of the knowledge strategy with the business strategy. (Hinkelmann et al., 2002, S. 73-76)

In the ensuing “Discover Knowledge Process” phase process knowledge is modelled. That means knowledge of the logical sequence of activities within a process, including participating organizational units, application systems and resources. In addition, knowledge with high potential impact is identified by experts. This includes decision-critical knowledge and knowledge to create a service or a product (functional knowledge). In addition, types of processed knowledge, knowledge carriers, knowledge flows and the forms of knowledge representation are recorded. After the modelling of business processes modelling and mapping of knowledge processes takes place in the third phase. Knowledge processes should replace knowledge flows by giving the knowledge flow a methodology. If an agent requires knowledge to carry out a task, then there are different options to obtain this knowledge. For example, he can turn to his colleagues or look up an expert using yellow pages. To make documents retrievable and therefore available for future use, they are enriched with metadata. A document gets a modification date, content keywords (tags) from folksonomies (collections of tags), an author and other information that are ideally already set by the appropriate knowledge structures and form the technical part of the organizational memory. (Hinkelmann et al., 2002, pp. 76-84)

Phase 4 “Making Knowledge Processes and Organisational Memory operational” implements these knowledge processes in existing software.

Hence, during his work an agent can see immediately which options he has to satisfy his knowledge needs. For example, a direct link to yellow pages for expert search can be provided, having context specific search parameters already set. An evaluation of the use of PROMOTE takes place in the 5th phase. Thus, the contribution of knowledge management can be measured by the success of the company. (Hinkelmann et al., 2002, pp. 84-90)

2.4 Declarative Configurable

Declarative Configurable (Deco) is a combination of declarative modelling, model verification and variability modelling to capture knowledge-intensive processes. In DeCo, the knowledge-intensive processes are modelled on three layers. The most abstract layer is at design. Here, a configurable, nondeterministic specification is created in accordance with the process goals. In the at-deployment layer, the process is configured in a context that is close to the application domain. Finally, a fully deterministic process execution trace that maps a single process instance is created in the at execution layer. (Rychkova and Nurcan, 2011, pp. 1-2)

Business processes are divided into prescriptive processes and descriptive processes. Prescriptive processes have predictable process flows, simple tasks, and can be fully specified at design time. At the opposite pole are the descriptive processes, which include the knowledge-intensive processes. .These complex tasks are based on cooperation between different actors, can only be outlined at design time. Principles underlying DeCo are: "Very little is certain at design-time" and "Fixed constraint often means lost opportunities". Therefore, nor control flow is required in the at-design layer for descriptive processes. Thus, the configurability remains unlimited and critical decisions can be made later on. (Rychkova and Nurcan, 2011, pp. 2-5)

Processes are configured in a specific context in the at-deployment layer in order to allow implementation for a certain application. Some details may not be pre-configured because of their vagueness. For configurable processes tasks are assigned to roles, tasks are arranged or selected rules are applied for example. In the at-execution layer, the pre-configured processes are finally carried out, leaving process tracks that are stored and thus contribute to the construction of a knowledge base and contribute to improving future processes. (Rychkova and Nurcan, 2011, pp. 2-9)

Hence, DeCo helps with the controlled assembly of important process specifications from predefined process parts or process variants. The design phase is controlled by central questions and after each execution possible new paths are incorporated in the initial or adapted model. The DeCo notation is an adaptation ofthe BPMN standard: Optional objects are marked by dashed lines, configurable objects by bold lines. Furthermore, objects are enriched by tags (e.g. <IN> for detailed information) in order to describe knowledge-intensive processes. Mainly the variability of knowledge-intensive processes is covered by this approach. (Rychkova and Nurcan, 2011, pp. 5-10)

2.5 GPO WM

Heisig (2002, pp. 47-59) shows with "Business Process Oriented Knowledge Management" (GPO-WM) is an eight-phase model for the introduction of knowledge management. Furthermore, the company's strengths and potentials related to the use of the resource "knowledge" can be determined. Important paradigms of GPO-WM are:

1. There should not be too much details in the models.
2. There should be a close connection between the method expert and the organization.

One possibility to keep a close connection to the organisation that is subject to a GPO-WM project could be the use of a company-specific modelling language. In order to put the focus on relevant tasks and processes, the central question "Does the task contain base activities of knowledge management?" is proposed. Basic tasks of knowledge management are generating knowledge, storing knowledge, transferring knowledge and applying knowledge.

During analysis, the focus is not on optimizing particular activities such as storing explicit knowledge in a database, but rather on consideration of the entire frame. Hence, questions like "Where is the generated knowledge reused?" are in the focus. Problems are identified based on guiding questions and possibly solved by best-practice solutions for knowledge management. Thus, problems can be discovered, which are not shown in a model. As a result, knowledge management modules are implemented and integrated into the respective business processes. (Heisig, 2002, pp. 59-64)

2.6 KIPN

França et al., (2012) noted that there are already numerous methods for modelling knowledge-

intensive processes and examine to what extent these can map knowledge-intensive processes regarding their specific process characteristics. Like Gronau (2009, pp. 69-71) in a similar study, they conclude that no approach from the literature covers all relevant aspects. França et al. made a step further and examined already established process modelling languages such as BPMN and EPCs based on the same criteria. It revealed that EPCs and BPMN already meet many of the requirements for the modelling of knowledge-intensive processes as defined by Remus (Remus, 2002, pp 115-116). Shortcomings are in the representation of poorly structured processes, the relationships to other business processes, knowledge transfer and the short half-life of knowledge.

As a result, França et al. propose an ontology (KIPO) for knowledge-intensive processes (França et al., 2012, pp 499-504) as the basis of the Knowledge Intensive Process Notation (KIPN). KIPN is a graphical notation which is composed of five diagrams. In the KIP diagram, activities are represented including business rules, relations and the level of abstraction. Modelling the control flow of individual activities is not mandatory in KIP diagrams. Communication between the actors, i.e. exchanged messages, knowledge acquisition and knowledge transfer, are shown in the socialization diagram. Finally, alternatives and their advantages and disadvantages are listed in a decision diagram. In addition, the notation provides diagrams for goal and for role modelling (França et al., 2013).

3 REVIEW OF THE PRESENTED APPROACHES

In the previous section, different approaches to handle knowledge-intensive business processes have been introduced. In the various approaches it is clear that knowledge-intensive processes need to be treated differently from normal processes due to their nature. All authors claim that setting the right focus of modelling is crucial for the output of an analysis. DeCo and KIPN recommend to diverge from the control flow orientation of many modelling languages. An alignment of knowledge or corporate objectives respectively is the starting point of any modelling or analysis project. KMDL provides the ability to model on the level of individuals and requires a strong incorporation of the modelled organisation in the modelling process. This results in a very context specific model which might not be transferable and might have limited maintainability due to the variability of knowledge-intensive processes as described in DeCo.

KPR recommends a distributed modelling. Due to a separate specification of concepts on one hand and concurrent activities at the other hand, semantic consistency can be guaranteed throughout the model.

For both - distributed modelling as well as a modelling in a central model – several modelling phases are proposed. In some approaches, the detailed modelling has a high priority for subsequent analysis, while GPO-WM discourages too high detailing. Most methods solve identified problems by the introduction of concrete knowledge management tools and their integration into the business processes. GPO-WM provides best practices that cover certain problem categories. The variety of objectives led to a multitude of different modelling languages. However, none of them was able to prevail in the literature to date.

Table 2 presents the main features of each approach in a summary. The idea is to provide a starting point for the selection of an existing approach depending on the modelling requirements. Furthermore, the limitations of existing should be emphasized.

Table 2: Characteristics of the approaches.

	KMDL	KPR	PROMOTE	DeCo	GPO-WM	KIPN
Goal	Process analysis and improvement	Strategic alignment	IT Support for WM	Process specification and analysis	KM implementation	Process specification and analysis
Methodology	+	+	+	+	+	-
Required tools	K-Modeler	ARIS	PROMOTE	tob e developed	-	-
Knowledge use/creation	+	+	+	-	+	+
Knowledge transfer	+	+	+	-	-	+
Knowledge resources	+	+	+	-	+	+
ICT	-	+	+	-	+	-
Organization	-	-	-	-	-	-
Treatment of complexity and variability	- High level of detail	o not addressed	o not addressed	+ Limited control flow orientation	+ High level of abstraction	+ Limited control flow orientation

In rows 1-3, general modelling aspects such as goals, methodological support and required tools are taken into account. These information can be used to assess the practical applicability. First, the goal of the modelling approach must fit to the goals of the modelling project. Key point is the project focus - is it a process improvement cycle on operational level or is it a strategic alignment? Furthermore, a modelling methodology as well as an appropriate toolset should be provided for the applicability of an approach.

The rest of the table addresses the specific requirements of modelling knowledge-intensive processes from Section 1 by a meta-analysis. Thus, the approaches are matched against the theory of knowledge intensive processes. Necessary modelling artefacts are identified and the existence of respective modelling constricts in the several approaches is assessed. Regarding knowledge activities (rows 4-5), there is a distinction between knowledge use/generation and the representation of knowledge transfers, because the latter is not covered by all approaches while generally all approaches address knowledge use and generation. A supplement to this is then the modelling of knowledge resources and their structures (row 6). The possibility of taking into account the technical infrastructure (ICTs) and organizational environment is considered in rows 7-8. The last row of the table aims at the ways how the approaches are dealing with the complexity and variability in the knowledge-intensive processes.

One result of the investigations is that all approaches fail to describe the organizational environment regarding knowledge intensive processes. Additionally, only two address the modelling of knowledge management system components in terms of ICT support (KPR, GPO-WM). Knowledge activities and knowledge resources on the other hand are well covered. Thus, the latter might be a starting point for model reuse in different contexts because they are present in the approaches independently from the defined goals.

4 CONCLUSION

Gai & Dang name three limitations of the process-oriented knowledge management (Gai and Dang, 2010, pp. 3-4):

1. Not all knowledge activities are associated with business processes. An example is the desire to communicate during a coffee break.
2. The variability of the processes is not well represented by many methods. Knowledge flows are changing and are not tied to static processes.
3. Tacit knowledge is often treated inadequately. Knowledge carriers are modelled as an attribute, but this is not enough to represent the flow of knowledge.

Limitation 1 generally applies to the approach of business process-oriented knowledge management. The context, in particular the organizational conditions have a significant impact on the performance of knowledge-intensive processes. This applies not only to knowledge activities performed outside the processes. The modelling approaches do not take this into account (see table 2). However, the context should be addressed in the models. The limitations 2 and 3 are only partially addressed too. As shown in table 2, not all of the approaches explicitly model the different possibilities of knowledge transfer. For dealing with the complexity and variability of knowledge-intensive processes two basic ways are being sought of: first, turning away from the control flow orientation and second a high abstraction level. It turns out that strategically oriented modelling approaches (GPO-WM, KPR) rely on a high level of abstraction, while approaches to detailed specification and analysis of processes (Deco, KIPN) have just little control flow orientation. Besides this straight forward distinction, guidelines for the application of particular method components need to be developed: Which approach fits best to what goals? How can the developed models be the base for a sustainable knowledge management? How can the effort and the benefits of the approaches be evaluated?

In summary, there are only ideas and assistance for addressing knowledge transfers in process-oriented knowledge management, but not a complete methodology. In a lot of cases, the consideration of process variability, of the organizational environment and a concrete methodology are missing. Furthermore, effort and benefits of knowledge management activities are poorly addressed.

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