KNOWLEDGE ENGINEERING PROCESSES AND TOOLS IN ENTERPRISE ENVIRONMENTS
A Systematization Attempt

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ABSTRACT

Despite a lot of persuasive scientific studies on the benefits of semantic technologies, Knowledge Engineering (KE) in enterprise environments is far away from wide practical implementation. The consultancy Gartner locates "Enterprise Taxonomy and Ontology Management" in its 2017 Hype Cycle for Emerging Technologies in the heart of the "Through of Disillusionment" with an expectation of 5-10 years to mainstream adoption. The paper aims at analyzing this contradiction and at investigating systematically the obstacles for successful and sustainable KE in enterprises. This is based on two case studies and an ethnographic study in organizations from different sectors: IT services and software production, public administration, and life sciences. For analyzing and visualizing characteristic use cases, processes and roles, methods of system analysis are applied; among others the triad of business process modeling BPMN, CMMN and DMN. A focus is put on the analysis and systematization of tools and services available for KE. The results of the paper form a basic framework for the constitution of KE as a business function crucial for bringing semantic technologies in enterprise environments to life.

1 INTRODUCTION

Structuring knowledge artifacts like books and documents, arranging them e. g. systematically in categories and thereby make them findable, is one of the traditional cultural practices of humans. The attempt of the formerly very popular search engine operator Yahoo, to redistribute websites through classification into categories, can be regarded as an adaptation of this cultural technique. There are many reasons for the failure of this attempt. Important structural differences can be observed between web knowledge and domain knowledge, as well as between the "population" of web users and domain experts in a particular field. In addition, the virtual space is free from traditional restrictions on physical spaces, numbering systems or representable relations. Finally, the machine-assisted indexing of documents based on text strings allowed an overwhelming speed with satisfactory precision for document search (Shirky 2005).

Without wanting to trace this development in all details, it can be stated that, particularly in the last 20 years, the documented knowledge of specialists - also in companies - has grown exponentially. In addition, knowledge workers and their economic contribution to performance are growing in importance. Currently, we are experiencing a (further) technologically fueled hype of artificial intelligence. Undoubtedly, the ability to examine large documents, huge amounts of data, or even big document corpora, recognize patterns and sort them, prepare them, and learn from them automatically is impressive. This applies in particular to the evaluation of huge, machine-collected data sets, the so-called big data. However, when evaluating knowledge artifacts, these methods remain below the level of interpretation in many circumstances. It is therefore not surprising that in the shadow of this hype "Enterprise Taxonomy and Ontology Management" as main activity in Knowledge Engineering (KE) experienced a renaissance, as shows the inclusion of this issue in the less noticed part of the Gartner's 2017 Hype Cycle for Emerging Technologies (Gartner 2017).

In fact, many companies struggle with the challenge of steadily growing, weakly structured and inadequately systematized knowledge artifacts. This applies e. g. to a life sciences company, which possesses in its archives an abundance of elaborated, high-quality scientific studies, the knowledge content of which is however not sufficiently (technically) accessible. Or a software producer whose service desk staff are faced with the challenge of having to answer ever more complex inquiries with a confusingly growing documentation. In practice, it becomes clear that the economically and professionally significant function of effectively and sustainably supporting knowledge workers in companies is little perceived and poorly managed. Roles are not clearly defined, processes out of focus, there is a lack of coherent budgeting, and quite practically a massive uncertainty about suitable tools.

The paper attempts to map this problem systematically and to give guidance to responsible persons as well as to knowledge workers themselves. To achieve this overall goal the remainder of the paper is structured as follows: Section 2 describes the detailed research objectives and the applied methodology reflecting the related work as well. Section 3 reveals the applied classification approaches, first for types of semantic networks in the context of distinct use cases and respective KE processes, and afterwards for roles and tools for KE in enterprise environments. In Section 4 reference models are provided for selected important KE processes identified in the previous section. Section 5 summarizes the findings of the paper in the shape of a basic framework for KE in enterprise environments, whereas Section 6 gives a short outlook on further work.

2 METHODOLOGY AND RELATED WORK

From the above-stated there come the following objectives of the paper:

1. With the purpose to clarify the research subjects and clarify the specific area of further research – to identify, describe and classify characteristic concepts of KE in enterprise environments: *KE use cases with respect to types of semantic networks, KE processes, KE roles and KE tools*.
2. With the objective to provide orientation about the applicability of KE tool types for different KE roles and use cases – to analyze the *scope of support of KE tools for KE roles and types of semantic networks*.
3. With the aim to provide essential building blocks of a basic framework for KE in enterprise environments – to develop reference models of selected KE processes: *knowledge schema development* and *knowledge schema updating* together with *change-related business rules.*

Classical methods of system analysis are used to achieve these objectives. The KE use cases, roles and processes are derived from two case studies and an ethnographic study in organizations from different sectors: IT services and software production, life sciences, and public administration. As a basic classification criterion, the complexity of the required semantic network in an enterprise environment like introduced in (Reichenberger 2010) is applied. The categorization of tools follows a non-exclusive grouping approach considering their main scope of application in association with characteristic competency requirements.
A portfolio analysis is conducted to reach the research objective 2. For reference modeling the triad of business process modeling standards provided by the OMG: BPMN, CMMN and DMN (OMG 2013, OMG 2016a, OMG 2016b) is applied.
To summarize the results and at once to reach research objective 3, an initial step for constructing a KE framework in enterprise environments is suggested. For this, the KE processes, which are the focus of this paper, must be considered as integral, but mostly technical-oriented parts of the overall knowledge management processes, like discussed in (Probst et al. 2010). This comprehensive work gives a detailed insight into processes and fine-grained team roles for knowledge management. The technical competencies are collected in the role "IT expert", whereas KE projects shows that classical IT experts, like web or software developers often miss specific KE competencies. Therefore, the taxonomy of roles suggested in this paper divides this comprehensive role in two different ones. Works related with the implementation of semantic applications or knowledge-based expert systems (e. g. Reichenberger 2010, Kurbel 1992, Creen and Kendal 2007) usually introduces the role of a knowledge engineer, often temporarily acting as an external expert in an implementation project. To establish KE as an integral business function this shall be considered as unsustainable.
Another area of relevant work can be found in business process management (BPM) and IT maturity frameworks. The BPM process landscape introduced by (Porter 1985) collects core processes in the center and accompanies them with support and management processes. This structure may be a candidate design pattern for a KE framework to be developed. From (CMMI 2010), the generic goals, which are processed in capability maturity models, are particularly interesting, covering the entire spectrum of the institutional anchoring of business processes. More specific (Sivasubramanian 2016) provides a process model for knowledge management based on CMMI.
A third area of relevant work concerns the methodological aspects of knowledge engineering in the context of semantic technologies. Initial principles of ontology engineering are provided in (Noy and McGuinness 2001). In (Nagypál 2007) are introduced two elaborated methodologies for ontology engineering together with best practices in ontology design. (Suárez-Figueroa et al. 2012) focusses on ontology engineering in a networked world. All works are mainly concerned with the development of highly-formalized OWL ontologies.

3 CLASSIFICATION APPROACHES

The weak access to knowledge artifacts in enterprise environments is the problem to be addressed by the findings of this paper, like described in Section 1. Data science methods and tools as well as KE for artificial intelligence or expert systems are not investigated. Therefore, characteristic use cases are taken as starting point for classification in Section 3.1. They are subsequently mapped to types of semantic networks and corresponding KE processes. The classification of KE roles provided in Section 3.2 is based on literature analysis together with generalized implications from conducted studies in enterprise environments. It is followed by a classification of tools which are investigated for their support quality for dedicated KE roles in Section 3.3.

3.1 Enterprise Use Cases, Semantic Networks and Knowledge Engineering Processes

The use cases introduced as starting points are taken from two case studies accompanied by KE activities and prototypical developments and one ethnographic study. They were performed in three different enterprise environments: IT services and software production, public administration, and life sciences. Table 1 collects these use cases and provides information about problems to be addressed by KE.

Table 1. Exemplary use cases for KE in enterprise environments

No	Industry	Description	Problems to be addressed
1	IT services and software production	- highly scattered, historically-grown product portfolio; - internal and external stakeholders use a variety of different terms	support service desk staff in answering to service requests by providing relevant documents independently from the wording used by customers
2	public administration	- historically-grown, distributed IT service infrastructure; - weakly structured service information is disseminated over different systems	enhance the availability of IT services for all groups of employees by providing group-specific access to highly interlinked service information
3	life sciences	- huge amount of elaborated, high-quality scientific studies on pharmaceuticals; - knowledge content of the studies is not sufficiently (technically) accessible	support company scientists in conducting product research by providing structured information based on previous studies

Use case 1 is mainly concerned with the naming of products and components organized in confusing bundles. In use case 2 weakly structured information about IT services are requested to bring into shape. Whereas use case 3 concerns the structure and content of scientific papers in a specific domain, which may implement specific rules and logic. Thus, different qualities of knowledge structures are requested. They can be mapped to different types of semantic networks (comp. Reichenberger 2010):

1. Thematic networks or terminologies,
2. Fact networks,
3. Ontologies.

Since ontology engineering on the one hand is extensively described in literature (comp. Noy and McGuinness 2001, Nagypál 2007, Suárez-Figueroa 2012) and on the other hand requires very specific competencies in abstract modeling, this paper will mainly focus on terminologies and fact networks. Both are types of semantic networks, i.e. they can be considered as semantic graphs. Table 2 compares terminologies and fact networks along their main structural features: class structure, variety of relations and attributes, treatment of instances, and their main engineering activities which can be derived from the structural features.

Table 2: Comparison of terminologies and fact networks as types of semantic networks

Feature	Terminology	Fact network
Class structure	all concepts (nodes) are representatives of the only class Concept, maybe collected in different thematic schemes	different classes for domain-specific types of entities, maybe organized in addition in a class hierarchy
Variety of relations	small set of generic relations: broader, narrower, related; maybe extended by custom relations	different domain-specific relation types in addition to generic relations, possibly with domain-range-specifications
Variety of attributes	different attributes for meta data: label, notes, definitions, custom attributes, maybe with language specifications	different general and domain-specific attributes, possibly with domain and data type specifications and language specifications for string attributes
Treatment of instances	all nodes are instances of the same class	instances are representatives of different classes; may be part of the schema, e. g. as enumerations for specific classes
Main engineering activities	manual editing of main schemes and concepts; automatic population by document or corpus analysis; manual curation	manual schema engineering and vocabulary reuse; population by different mapping, integration, and validation technologies

For the following investigations, the main engineering activities obtained in Table 2 are aggregated in three KE process areas relevant in enterprise environments:

1. Terminology development & administration,
2. Knowledge schema development & updating,
3. Fact network population & curation.

3.2 KE Roles and Tools for Use in Enterprise

In the frame of this work, KE shall be restricted to the set of activities for the production, maintenance and curation of that knowledge structures in enterprise environments, which support the access to knowledge artifacts technically and thus support knowledge workers in their productive tasks. From the main engineering activities listed in Table 2 can be deduced, that a knowledge engineer plays an intermediary role between business domain experts and IT experts. To this extent, it can be compared with the role of a business analyst in classical IT projects. It differs though substantially from that role in two aspects. Firstly, knowledge engineers often have to deal with a multitude of different business domain experts. Secondly, the results of their work are not merely IT system requirements, but first class technical artifacts providing a basic structure to the IT system to be developed and/or maintained. Fig. 1 compares business analysts and knowledge engineers in their intermediary role.

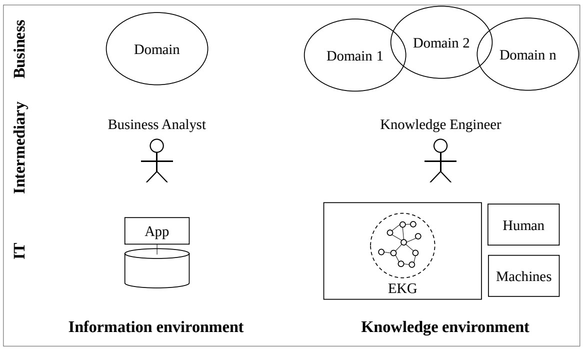

Figure 1: Comparison of Intermediary Roles

In addition to their operational activities, knowledge engineers are involved in the management of projects for system development and processes for system operations and maintenance. Thus, three additional management roles in the context of KE shall be considered. Table 3 summarizes the KE roles like discussed above. Nevertheless, for the portfolio analysis of KE roles and tools the managerial roles will be left out, since their work is sufficiently supported by traditional management tools.

Table 3: KE roles in operation and management

Operational roles	Managerial roles
Business domain expert KE expert IT expert	Product owner Project manager Process owner

To provide a classification of tool types for KE in the considered field, the following sources were analyzed: W3C wiki pages for ontology editors (W3C 2015) and terminology editors (W3C 2010), the Ontology page of (Wikipedia 2017), and a scientific paper studying tool support for non-expert ontology engineering (Siricharoen 2016). None of these references provides a classification of tools. Only the W3C provides a differentiation by issuing two different pages for ontology and terminology editors respectively. Real-world tools can be upgraded or downsized depending on implemented features, modules or plug-ins, which makes it difficult to classify them strictly. For matching a use case and the conditions in an enterprise environment, specifying the necessary type of tool is nevertheless a valuable decision support. A complete market analysis is outside the focus of this paper. Interested readers are suggested to use the mentioned references.
Like discussed above, a use case can be matched to one of the three types of semantic networks. Engineering tools for more complex networks usually can be used for less complex ones too. But, this may be a bad decision for practical matters. As criteria defining the implementation environments are chosen:

(i) as a user-oriented aspect, the leading user interface of the tool and
(ii) as a project-related one, the range of functions required by the project.

There are four different user interfaces: code, tree, template, and graphic. The range of functions required by a project will be differentiated qualitatively as narrow, medium, large or very large. Table 4 shows the classification of KE tools with their characteristics. The highlighted table cells indicate the criterion leading for the classification together with its value. In six of seven cases, this value is exclusive for the respective criterion.

Table 4: Classification of KE tools

Tool type	Semantic network type	Main user interface	Range of functions
Plain RDF editor	ontology	code	narrow
Terminology manager	terminology	tree	medium
Semantic Wiki editor	fact network	form	medium
Graphical editor	fact network	graphic	narrow
Ontology editor	ontology	tree	medium
Ontology manager	ontology	tree	large
Semantic IDE	ontology	tree	very large

With the results presented in the Tables 2-4 the first objective of the paper: to identify, describe and classify characteristic concepts of KE in enterprise environments is reached.

3.3 Portfolio Analysis for KE Tools

The scope of support for KE roles and semantic networks provided by different types of KE tools will now be discussed and visualized in the shape of a portfolio analysis. This will fulfill the second research objective of the paper stated in Section 2. As already mentioned in the context of Table 3, only the operational roles are included in the subsequent analysis. They are briefly outlined here.

Business Domain Experts (BDE) are the knowledge workers acting in business processes and carrying the business knowledge in a specific domain. Often in semantic projects several domains are involved. Thus, the BDE role is often taken by several persons being experts in different domains. This may imply difficulties in mutual understanding, even on the level of terms used for business concepts.

Knowledge Engineering Experts (KEE) in enterprise environments are primarily skilled in KE methods and technologies for eliciting, structuring and formalizing business knowledge. They act as intermediaries between the business and the IT parties and therefore must at least be able to grasp their needs, expectations, constraints, and external interfaces.

IT experts (ITE) are the developers, administrators and operators of semantic applications. I. e., they are responsible for business applications implementing semantic technologies or artifacts in its architecture, data structure and/or content, at least partially. Since semantic technologies implies a paradigmatic shift in knowledge representation and formalization, the requirement for an ITE are quite specific.

While the BDEs are apparently internal actors within a company, the other roles are often taken by external specialists. This may be a good solution for pushing and finishing a knowledge-oriented development project. On the other side, external specialists tend to overlook business specifics, guided by their experiences from other projects. What is an advantage in formal and methodical aspects may be a disadvantage for really grasping the needs, expectations, constraints etc. Moreover, since knowledge in enterprise environments is very fluid, systems developed by external experts take risk to become outdated and therefore rejected soon, if the mentioned roles will not be taken over by internal experts.

Fig. 2 shows the result of a portfolio analysis of KE tools like classified in Table 4. It was analyzed for each type of tool, which KE role is mainly addressed and supported, and which kind of semantic network it allows to engineer primarily.

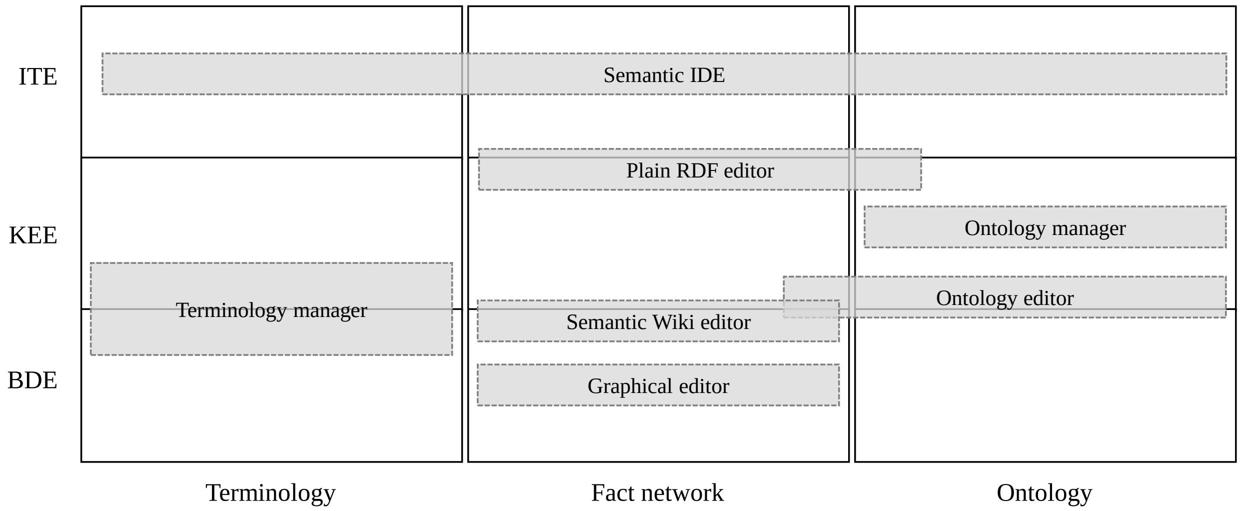

Figure 2: Portfolio of KE Tools with Respect to KE Roles and Types of Semantic Networks

To conclude this section, the results of the portfolio analysis will be reflected and illustrated in the frame of use cases from the mentioned above enterprise environments (comp. Table 1).

Service desk in a software company. All KE roles are basically represented by internal employees. Deficits were the following: (i) terminology is collected and maintained in a MS Excel file stored at MS SharePoint, (ii) not all desirable relations and attributes are recordable, (iii) the technical implementation affords cumbersome adjustments after each terminology update. The KEE is installed as a temporarily role within an internal project. Implementing a commercial terminology management tool was rejected, since the products available on the market are over-sized for the narrow application or doesn't provide an adequate visualization, and at the same time are too costly. As a feasible compromise, the ontology editor Protégé was downsized to SKOS-based terminology editing and on the other hand upgraded to visualizing chosen parts of the terminology. This was realized by the adaptation of openly available and the development of custom plug-ins. Collaborative further development of the terminology is realized via version control.

IT services catalog in a public administration. KEE and ITE act as internal experts, but again, in the frame of a research project. Knowledge about IT services in the organization was totally unstructured and disseminated over a multitude of systems and pages, without any institutionalized knowledge management. The requirements and the basic structure of the fact network were elaborated in team workshops and expert interviews. A multitude of tools was investigated, but no one meets all requirements. Fig. 2 reflects this result very well: there is no tool type really focusing on fact network engineering. Thus, a combination of tools was used: the plain RDF editor rdfEditor for coding, Protégé for structure control and visualization, and GitHub for documentation and version control. This was possible, since each participant takes at least two of the three roles.

Research in a life sciences company. Because of the highly specialized kind of domain knowledge, the role of a KEE here is extremely challenging. It seems inevitable to engage a person directly from the domain. Moreover, the KE itself is much more sophisticated than in the previous use cases. Thus, the KEE must be very well trained in formal KE methods. For closing the gap, external scientists will be engaged. After revising a couple of tools on the market, the powerful Top Braid Composer was acquired. On the one hand, this ensures that networks of any complexity can be modeled. On the other hand, this tool also includes functions of a semantic IDE, so that the highly specialized BDE can be involved via custom-built interfaces. Now, the project is still at its start. Because of the intended paradigm shift in documenting and storing scientific knowledge artifacts, the anchoring of ITE with solid expertise in semantic technologies seems to be an important factor for the sustainable success of the project. To sum up, the chosen market tool covers the tool types ontology editor, ontology manager and semantic IDE. To address the needs of BDE, specific tools must be developed which minimizes the efforts for them and ensures the quality of a growing ontology-based knowledge base.

4 REFERENCE PROCESSES FOR KNOWLEDGE ENGINEERING

In Section 3.1 three aggregated process areas relevant for KE in enterprise environments are defined. The first refers to use cases for terminology engineering, whereas the remaining two covers use cases requiring the implementation of fact networks. Since the second process area Knowledge Schema Development & Updating is the most challenging, it was selected for detailed analysis and modeling. The term knowledge schema was chosen, since developing and updating the structural elements of a fact network are in the focus of engineering activities. Processes for the population of fact networks are mostly related with data mapping and automatic integration, whereas the curation of fact networks requires either less technical activities performed by BDE or the application of sophisticated data science methods. All these activities are not at the core of KE.

The models for the chosen process area are provided in all three BPM modeling standards (OMG 2013, OMG 2016a, OMG 2016b). Like suggested in the respective specifications, BPMN is chosen for processes following strict procedures. When a process or subprocess allows a wide range of free plannable activities largely depending on specific circumstances, CMMN is to prefer over BPMN. Process activities implementing strict business rules are called decision tasks. In this case, DMN is the method of choice. Experienced and highly competent practitioners have clearly shown that BPMN can be modeled at different levels of granularity (Silver 2009, Freund and Rücker 2016). Thus, the knowledge schema development process is modeled on a coarser, strategic level, whereas the knowledge schema updating process is shown as analytic model.

4.1 Knowledge Schema Development

Like already discussed in Section 3.2, knowledge engineering in enterprise environments requires the cooperation of at least three different groups of experts, referred to as KE roles. The development process requires an even closer cooperation. Hence for BPMN modeling, a single pool with three lanes is preferred over a collaboration model. Two of this three lanes are intended for modeling team activities (Fig. 3). The process starts when a KE project is initialized. The first activity *Preparing the workspace*, is provided in CMMN (Fig. 4) because of its complexity and variability.

Knowledge schema development at the first is engaged in requirements engineering, performed as parallel (independent) tasks in two different teams: business team and technical team. The core development activities are collected in a loop subprocess, which is involved in an explicit outer feedback loop. Last activity results in the formal serialization of the knowledge schema. Since this process is modeled at a strategic level, activities are not specified further.

This is different with the subprocess, modeled as a so-called case. Activities are classified as human (blocking or non-blocking), process, or case tasks and further specified as pre-planned, discretionary, required, repeated, manually activated, or auto-completing. Two logical groups of activities (stages) are modeled as independent. They are supplemented by non-grouped, discretionary tasks and plan fragments as well as event listeners for being able to react to unforeseen events and particular situations. The subprocess Prepare project workspace starts automatically after a KE project is initialized with the task: Analyze project charter. At the same time, all the elements that have no input sentries are enabled. As indicated by connectors labeled with complete, the remaining elements will be enabled after completion of their predecessors. A process task starts a BPMN process following strict procedures, and a case task enables another case or a subcase.

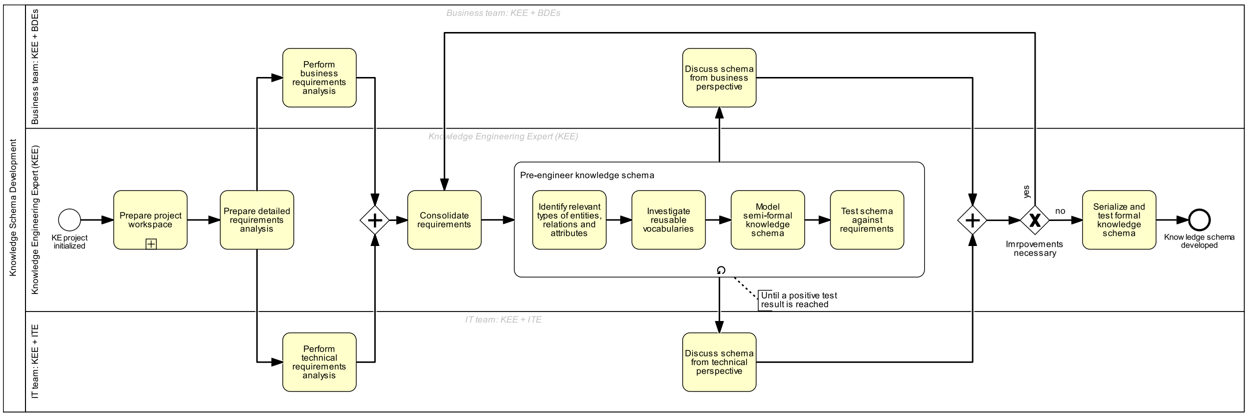

Figure 3: Strategic BPMN Model of the Process: Knowledge Schema Development

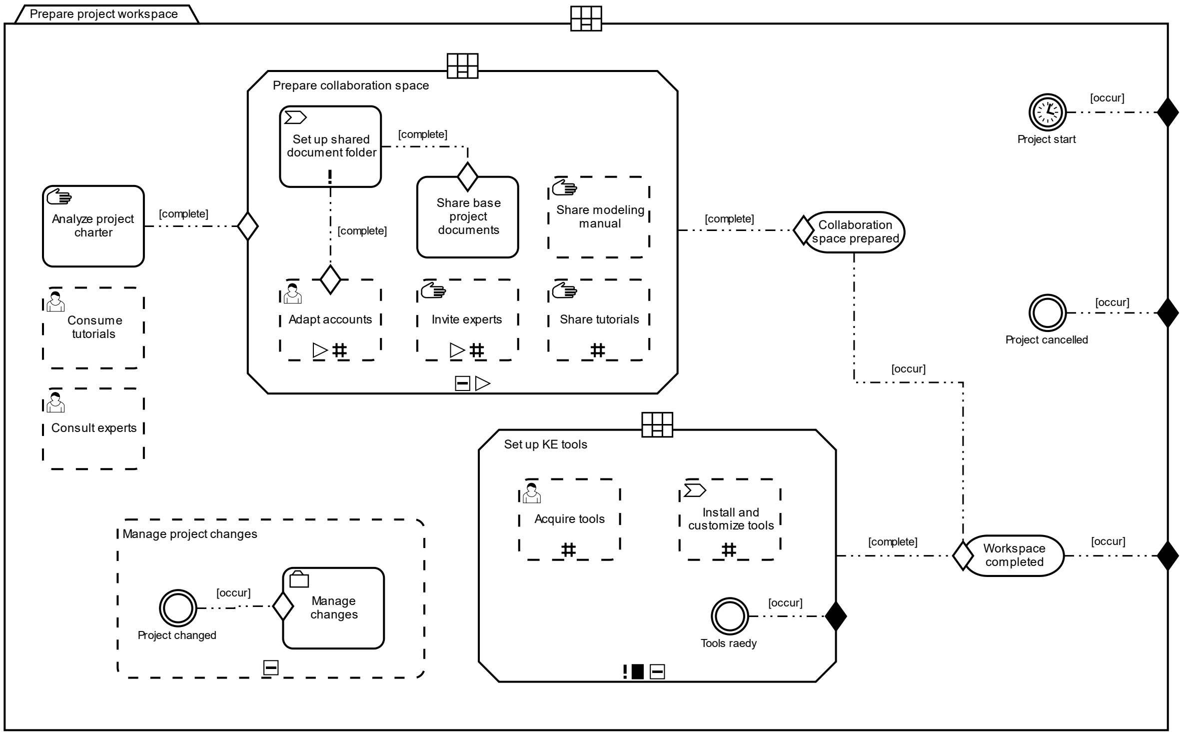

Figure 4: CMMN Model of the Subprocess: Prepare Project Workspace

4.2 Knowledge Schema Updating

The Knowledge Schema Updating process is required both within an implementation project as well as in the subsequent operation of a semantic application. During the project, it is caused by development iterations. Afterwards different business, usage or technical problems or change request may start the process. The process is modeled at an analytic level (Fig. 5). Hence, all atomic activities and intermediate events are specified. Since a multitude of events may cause the process start, the initialization is modeled with an event-based gateway. Two complex activities concerning the schema extension and refactoring are not modeled in detail and depicted as subprocesses. The process activities are primarily performed by the KEE. Thus, the central pool is not subdivided in lanes. The inevitable communication with BDE, ITE and end users is modeled with message flows. However, communication with experts within the two subprocesses was not presented in order not to overload the model.

To conclude the section, the business rule task Qualify Request is to be analyzed in more detail. The DMN method is available for this purpose. Its output value is supposed to route the sequence flow through the exclusive gateway in the updating process. Three different values are possible: (i) minor editing of the schema which can be performed by the KEE without further consultation, (ii) schema is expected to have an extended coverage, (iii) the schema must be refactored. The last two cases lead to complex sub processes that require close cooperation with BDE and ITE and which are not modeled in detail. For modeling the input values for the decision are used the features given in Table 2 for specifying types of semantic networks (Fig. 6).

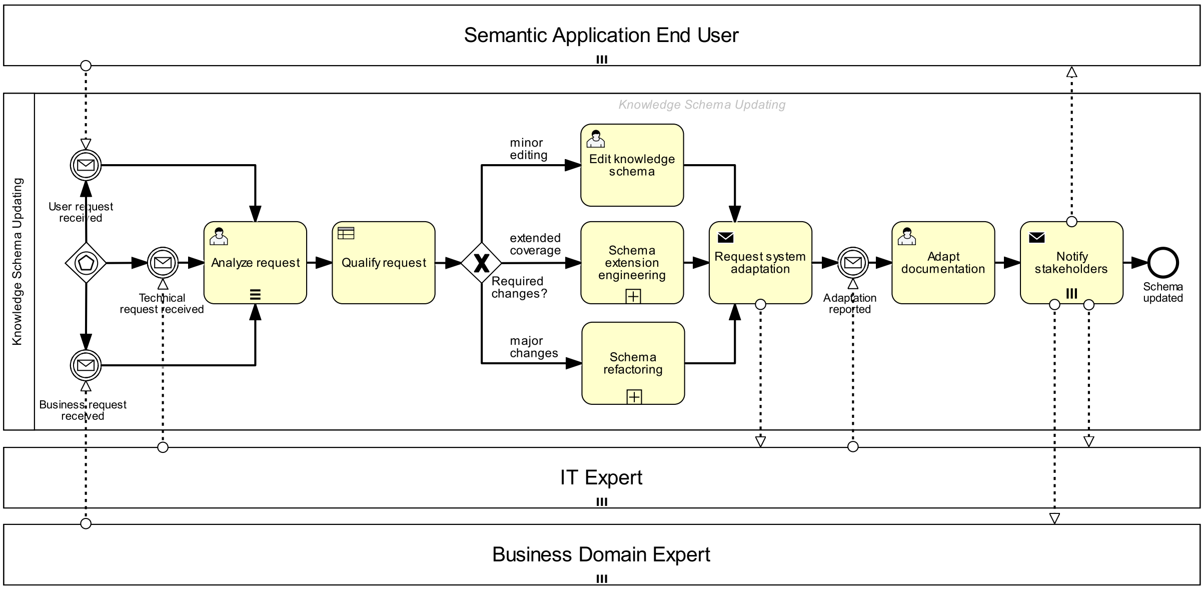

Figure 5: Analytical BPMN Model of the Process: Knowledge Schema Updating

Table 5: DMN Rule Sheet Qualify Request

F	Input values				Output value
	Class changes	Relation changes	Attribute changes	Instance changes	Qualification
	{Update class metadata, Adding classes, Refactoring class structure}	{Update relation metadata, Adding relations, Refactoring relations}	{Update attribute metadata, Adding attributes, Refactoring attributes}	{Update instance metadata, Adding instances, Refactoring instances}	{Minor editing, Extended coverage, Major changes}
1	= Update class metadata	= Update relation metadata	= Update attribute metadata	= Update instance metadata	Minor editing
2	= Refactoring class structure	–	–	–	Major changes
3	–	= Refactoring relations	–	–	Major changes
4	–	–	= Refactoring attributes	–	Major changes
5	–	–	–	= Refactoring instances	Major changes
6	–	–	–	–	Extended coverage

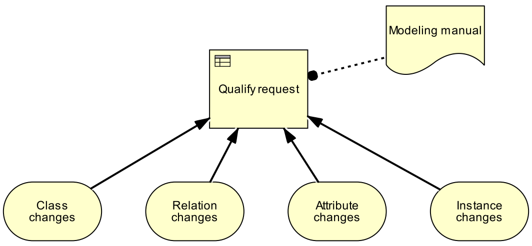

Figure 6: DMN DRD Qualify Request

The decision rules are modeled in the shape of a rule sheet (Table 5), natively supported by DMN. For all input variables three different values are identified: (i) a minor change only concerning the metadata, (ii) a request for adding items, and (iii) the necessity for refactoring items or their structure. To obtain a slim rule model, hit policy First (F) is chosen. This allows to reduce the overall number of rules from 81 to 6.

5 BASIC FRAMEWORK FOR KE

With the results of the Sections 3 and 4, an initial set of building blocks of a framework for KE in enterprise environments is provided. To reach the final objective, the structure of this framework shall be outlined. As a central artifact for overview and navigation, a process landscape is suggested (Fig. 7).

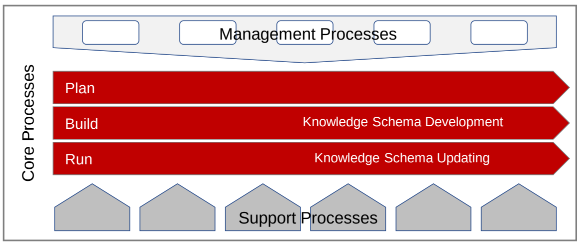

Figure 7: Process Landscape in the Shape of a Porter Diagram (Porter 1985) with Exemplary KE Processes

For each process, specific goals like applied in (CMMI 2010) shall be collected. Unlike CMMI, the specific practices and sub practices should not only be described, but also visualized by process diagrams, as shown in Section 4. This allows a better understanding of procedures and responsibilities for a single process, and of interrelations between different processes. The system of generic goals introduced in CMMI can be easily adopted for KE. This will enable the management in enterprise environments to assess their own maturity regarding KE and hopefully lead to higher success rates and sustainable implementations of semantic applications. Table 6 provides a first glance at this adoption and expected benefits.

Table 6: CMMI Generic Goals and Practices with their Adoption to KE

CMMI generic goals and practices		Adoption to KE
GG 1	Achieve specific goals	
GP 1.1	Perform specific practices	at least for the most important processes in the process landscape
GG 2	Institutionalize a managed process	
GP 2.1	Establish an organizational policy	make KE and its importance visible on management level, ensure initial governance by providing important guidelines
GP 2.2	Plan the process	define milestones and intersection points
GP 2.3	Provide resources	e.g. adequate tools, platforms and time budgets
GP 2.4	Assign responsibility	define all KE roles: BDE, KEE, ITE, as well as management roles
GP 2.5	Train people	for specific KE methods and tools and for general methods of elicitation and documentation
GP 2.6	Control work products	define and assess competency questions
GP 2.7	Identify and involve relevant stakeholders	users of a KE application and other groups of IT system stakeholders
GP 2.8	Monitor and control the process	define KE specific performance indicators and measure them
GP 2.9	Objectively evaluate adherence	install reflection workshops
GP 2.10	Review status with high level management	negotiate target agreements, institutionalize regular review workshops
GG 3	Institutionalize a defined process	
GP 3.1	Establish a defined process	standardize KE procedures, tool chains, best practices etc.
GP 3.2	Collect process experiences	provide and maintain a knowledge base about KE

6 FUTURE WORK

The initial motivation of the investigations presented in the paper was the observed lack of systematic management guidelines for KE projects which causes a lot of uncertainty and a high risk of project underachievement. The provided approaches for analyzing, systemizing and modeling concepts, structures and procedures of KE in enterprise environments form not more than a basic nucleus for such a management framework. A big amount of work is to do down the road for reaching a state that give real support for KE activities outside the academic sphere: (i) the process landscape must be filled up and completed with all processes essential for KE, (ii) for each process, descriptions and models with adequate granularity shall be provided suggesting tools and roles with respect to use cases, (iii) the maturity model must be elaborated, and (iv) the overall framework shall be put on a semantic basis and provided in an easy to use way. Finally, the framework and its artifacts should be tested in different enterprise environments and subsequently further improved.

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