A Model-Based Taxonomy of Knowledge Development Scenarios

Eckhard Ammann, Ismael Navas-Delgado, and José F. Aldana-Montes

***Abstract*— Knowledge development in an enterprise is about approaches, methods, techniques and tools, that will support the advancement of individual and organizational knowledge for the purpose of an improvement of businesses. A modeling basis for knowledge development is provided with a new conception of knowledge and of knowledge conversions, which introduces three dimensions of knowledge and general conversions between knowledge assets. This modeling basis guides the definition of a taxonomy of knowledge development scenarios. In this taxonomy, constructive and analytic scenarios are distinguished as main categories and subsequently refined into more specific ones. In order to indicate the usefulness of this taxonomy, example implementations of two knowledge development scenarios are briefly outlined: a modeling notation for knowledge-intensive business processes as a constructive scenario and a rule-processing system based on a knowledge ontology as an analytic scenario.**

***Index Terms*— knowledge development, application scenarios, conception of knowledge, knowledge conversions, knowledge-intensive business processes, rule processing.**

I. Introduction

Knowledge development in an enterprise is about approaches, methods, techniques and tools, that will support the advancement of knowledge for the purpose of an improvement of businesses. This notion includes as well individual knowledge as group and organizational knowledge. It can be seen as integral part of knowledge management, see [1], [9] and [11] for a description of several existing approaches for knowledge management. While the management aspect of knowledge management seems to be rather well understood and practised in many companies [11], there is no common concept and understanding of knowledge and of knowledge development as basis of it.

In this paper we investigate and classify possible application scenarios for knowledge development. This leads to a taxonomy of knowledge development scenarios. This taxonomy is based on a new conception of knowledge and knowledge development, which is shortly described in this paper (see [2] for a complete description).

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The conception of knowledge is represented by a knowledge cube, a three-dimensional model of knowledge with types, kinds and qualities. Using this conception we introduce general knowledge conversions between the various knowledge variants as a model for knowledge dynamics and development in the enterprise. First a basic set of such conversions is defined, which extends the set of the four conversions of the well-known SECI-model [12]. Building on this set, general knowledge conversions can be defined, which reflect knowledge transfers and development more realistically and do not suffer from the restrictions of the SECI-model.

Built on this conception, application scenarios for knowledge development are classified. Application scenarios are understood as typical processes, which lead to an advancement of individual and organizational knowledge in the enterprise.

Two main categories of application scenarios are identified: constructive and analytic scenarios. Constructive scenarios build knowledge development processes. For example, knowledge dynamics in knowledge-intensive business processes can be modeled. Analytic scenarios can be represented by general nets of general knowledge conversions, which are introduced in this paper. They are characterized by gaps, i.e., by unknown knowledge or conversion parts in these nets. Important knowledge development requirements in an enterprise can be covered by analytic scenarios. Assume for example, that the knowledge requirements for a project are known as well as the learning options in the company. From that, one would try to identify minimal knowledge requirements for a new employee, which should work in the project and should be able to fulfil the requirements of this scenario at least after some learning efforts.

At least for simple cases, analytic scenarios can be supported by a rule-processing system based on a knowledge ontology, which has been built as representation of our knowledge and knowledge dynamics concept. A set of corresponding rules for addressing these scenarios and their representations has been developed. Therefore, possible solutions for those scenarios, i.e. filling the gaps in the scenarios, can be gained.

The structure of the paper is as follows. After an introduction and section II on related work, the two sections III and IV will introduce the knowledge conception and general knowledge conversions between knowledge and information assets, respectively. Section V discusses knowledge development scenarios and presents a taxonomy of these scenarios, while section VI outlines example implementation of the two main scenario categories. Finally, section VII summarizes and concludes the paper.

II. Related Work

One specific approach for enterprise knowledge development is EKD (Enterprise Knowledge Development), which aims at articulating, modeling and reasoning about knowledge, and which supports the process of analyzing, planning, designing, and changing your business; see [8] and [5] for a description of EKD. EKD does not provide a conceptual description of knowledge and knowledge development.

For the conception part, there exists one well-known approach by Nonaka/Takeuchi [12], which is built on the distinction between tacit and explicit knowledge and on four knowledge conversions between the knowledge types (SECI-model). However, many discussions exist, whether to interpret the explicit knowledge part as still bound to the human being, or as already detached from him. Also the linear spiral model of knowledge development has turned out to be limiting.

Another important work is the introduction of the type/quality dimensions of knowledge in [7]. Finally, important distinctions of implicit knowledge are given in [10].

III. Conception of Knowledge

A. General Understanding of Knowledge

In this section we briefly provide a conception of knowledge, and of knowledge types, kinds and qualities. More details can be found in [2]. As our base notion, knowledge is understood as justified true belief, which is (normally) bound to the human being, with a dimension of purpose and intent, identifying patterns in its validity scope, brought to bear in action and with a generative capability of new information, see [7], [8] and [12]. It is a perspective of "knowledge-in-use" [7] because of the importance for its utilisation in companies and for knowledge management. In contrast, information is understood as data in relation with a semantic dimension, but is lacking the pragmatic and pattern-oriented dimension, which characterises knowledge.

We distinguish three main dimensions of knowledge, namely types, kinds and qualities, and describe those in the following three sub-sections. The whole picture leads to the three-dimensional knowledge cube, which is introduced at the end of this section.

B. Type Dimension of Knowledge

The type dimension is the most important for knowledge management in a company. It categorizes knowledge according to its presence and availability. Is it only available for the owning human being, or can it be communicated, applied or transferred to the outside, or is it externally available in the company's organisational memory, detached from the individual human being? It is crucial for the purposes of the company, and hence a main goal of knowledge management activities, to make as much as possible knowledge available, i.e. let it be converted from internal to more external types of knowledge.

Our conception for the type dimension of knowledge follows a distinction between the internal and external knowledge types, seen from the perspective of the human being. As third and intermediary type, explicit knowledge is seen as an interface for human interaction and for the purpose of knowledge externalisation, the latter one ending up in external knowledge. Internal (or implicit) knowledge is bound to the human being. It is all that, what a person has "in its brain" due to experience, history, activities and learning. Explicit knowledge is "made explicit" to the outside world e.g. through spoken language, but is still bound to the human being. External knowledge finally is detached from the human being and may be kept in appropriate storage media as part of the organisational memory. Fig. 1 depicts the different knowledge types.

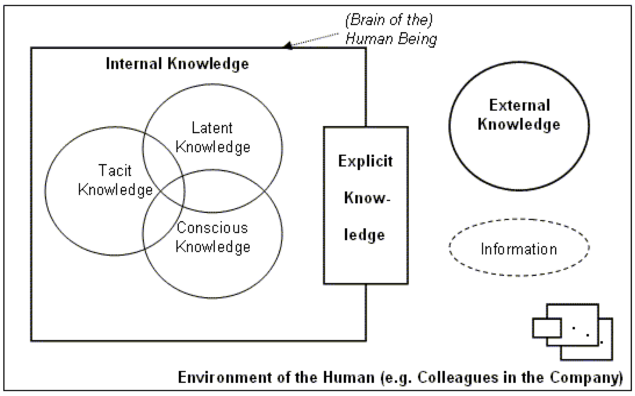

Fig. 1 Conception of knowledge types

Internal knowledge can be further divided into tacit, latent and conscious knowledge, where those subtypes partly overlap with each other, see [10]. Conscious knowledge is conscious and intentional, is cognitively available and may be made explicit easily. Latent knowledge has been typically learning as a by-product and is not available consciously. It may be made explicit, for example in situations, which are similar to the original learning situation, however. Tacit knowledge is built up through experiences and (cultural) socialisation situations, is specific in its context and based on intuition and perception. Statements like "I don't know, that I know it" and "I know more, than I am able to tell" (adapted from Polanyi [13]) characterise it.

C. Kind Dimension of Knowledge

In the second dimension of knowledge, four kinds of knowledge are distinguished: propositional, procedural and strategic knowledge, and familiarity. It resembles to a certain degree the type dimension as described in [7]. Propositional knowledge is knowledge about content, facts in a domain, semantic interrelationship and theories. Experience and practical knowledge and the knowledge on "how-to-do" constitutes procedural knowledge. Strategic knowledge is meta-congitive knowledge on optimal strategies for structuring a problem-solving approach. Finally, familiarity is acquaintance with certain situations and environments, it also resembles aspects of situational knowledge, i.e. knowledge about situations, which typically appear in particular domains [7].

D. Quality Dimension of Knowledge

The quality dimension introduces five characteristics of

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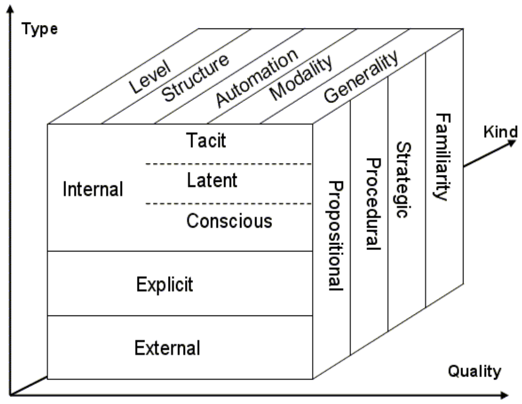

Fig. 2 The knowledge cube

knowledge with an appropriate qualifying and is independent of the kind dimension, see [7].

The level characteristics aims at overview vs. deep knowledge, structure distinguishes isolated from structured knowledge. The automation characteristic of knowledge can be step-by-step-doing by a beginner in a domain of work or automated fast acting by an expert. All these qualities measure along an axis and can be subject to knowledge conversions (see section III). Modality as the fourth quality of knowledge asks for the representation of it, be it words versus pictures in situational knowledge kinds, or propositions versus pictures in procedural knowledge kinds. Finally, generality differentiates general versus domain-specific knowledge. Knowledge qualities apply to each knowledge asset.

E. The Knowledge Cube

Bringing all three dimension of knowledge together, we gain an overall picture of our knowledge conception. It can be represented by the knowledge cube, as is shown in Fig. 2. Note, that the dimensions in the knowledge cube behave different. In the type and kind dimensions, the categories are mostly distinctive (with the mentioned exception in the sub-types), while in the quality dimension each of the given five characteristics are always present for each knowledge asset.

IV. Knowledge Conversions

In this section we give a conception of knowledge conversions. The transitions between the different knowledge types, kind and qualities are responsible to a high degree for knowledge development in an organisation. More details can be found in [2].

Most important for knowledge management purposes are conversions between the knowledge types and they will be the focus in the following. Among those, especially those conversions making individual and internal knowledge of employees usable for a company, are crucial for knowledge management. The explicitation and externalisation conversions described in this section achieve this. Implicitly socialisations between tacit knowledge of different people also may contribute to this goal.

Conversions in the kind dimension of knowledge are seldom, normally the kind dimension of knowledge remains unchanged in a knowledge conversion changing the type dimension. Those in the quality dimension are mostly knowledge developments aiming at quality improvement and will not change the type and kind dimensions of the involved knowledge assets.

Five basic knowledge conversions (in the type dimension) are distinguished here: socialisation, explicitation, externalisation, internalisation and combination. Basic conversion means, that exactly one source knowledge asset is converted into exactly one destination knowledge asset and that only one knowledge dimension is changed during this conversion. More complex conversions may be easily gained by building on this set as described later in this section. They will consist of m-to-n-conversions and include information assets in addition.

Socialisation converts tacit knowledge of one person into tacit knowledge of another person. For example, this succeeds by exchange of experience or in a learning-by-doing situation under supervision of an experienced person. Explicitation is the internal process of a person, to make internal knowledge of the latent or conscious type explicit, e.g. by articulation and formulation (in the conscious knowledge type case) or by using metaphors, analogies and models (in the latent type case). Externalisation is a conversion from explicit knowledge to external knowledge or information and leads to detached knowledge as seen from the perspective of the human being, which can be kept in organisational memory systems. Internalisation converts either external or explicit knowledge into internal knowledge of the conscious or latent types. It leads to an integration of experiences and competences in your own mental model. Finally, combination combines existing explicit or external knowledge in new forms. These five basic knowledge conversions are shown in Fig. 3.

As generalisation of basic knowledge conversions, general knowledge conversions are modeled converting several source assets (possibly of different types, kinds and quality) to several destination assets (also possibly different in their knowledge dimensions). In addition, information assets are considered as possible contributing or generated parts of general knowledge conversions.

For example, in a supervised learning-by-doing situation seen as a complex knowledge conversions a new employee may extend his tacit and conscious knowledge by working on and extending an external knowledge asset in a general conversion, using and being assisted by the tacit and conscious knowledge of an experienced colleague. A piece of relevant information on the topic may also be available on the source side of the conversion. Here on the source side of the general conversion we have two tacit, two conscious and one external knowledge assets plus one information asset, while on the destination side one tacit, one explicit

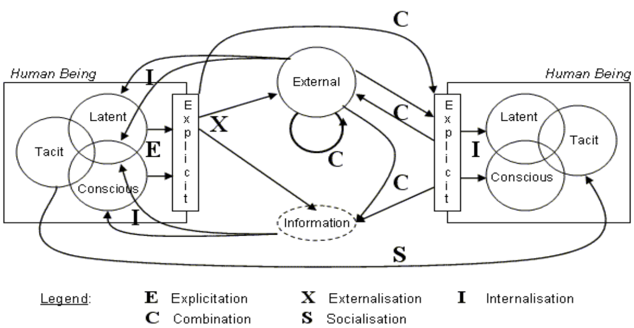

Fig. 3 Knowledge conversions in the type dimension

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and one external knowledge asset (i.e. the resulted enriched external knowledge) arise.

Completing this section, we shortly mention knowledge conversions in the quality dimension of knowledge. In three out of the five quality measures, basic conversions can be identified, which are working gradually. Those are, firstly, a deepening conversion, which converts overview knowledge into a deeper form of this knowledge. Secondly a structuring conversion performing improvement in the singular-versus-structure scale of the structural measure. Finally, conscious and step-by-step-applicable knowledge may convert into automated knowledge in a automation conversion, which describe a process from beginner to expert in a certain domain. The remaining two quality measures of knowledge, namely modality and generality, do not lend themselves to knowledge conversions. They just describe unchangeable knowledge qualities.

V. Knowledge Development Scenarios

In this section, application scenarios for knowledge development are classified. Application scenarios are understood as typical processes, which lead to an advancement of individual and organizational knowledge in the enterprise.

Two main categories of application scenarios are identified: constructive and analytic scenarios. Both can be reduced to single or multiple general knowledge conversions. While constructive scenarios build knowledge development processes, analytic scenarios are characterized by gaps, i.e., by unknown knowledge or conversion parts in knowledge development nets. The two categories are described in the following two sub-sections. In sub-section C, a taxonomy of knowledge development scenarios will be provided and depicted in Fig.4.

A. Constructive Scenarios

Constructive scenarios build knowledge development processes. For example, knowledge dynamics in knowledge-intensive business processes can be modeled. The set of constructive scenarios includes (pure) knowledge development processes, with the advancement of knowledge as main and single goal. Furthermore normal business processes, which lead to knowledge development effects as a kind of "by-product", for example, by making process participants more experienced for future process deployments. And finally knowledge-intensive business processes, where the advancement of knowledge is an integral part of the process, see our example of supervised learning-by-doing in section IV.

B. Analytic Scenarios

Analytic scenarios can be represented by general nets of general knowledge conversions, which have been introduced in section IV. They are characterized by gaps, i.e., by unknown knowledge or conversion parts in these nets. Important knowledge development requirements in an enterprise can be covered by analytic scenarios. Assume for example, that the knowledge requirements for a project are known as well as the learning options in the company. From that, one would try to identify minimal knowledge requirements for a new employee, which should work in the project and should be able to fulfil the requirements of this scenario at least after some learning efforts. This scenario in fact is a simple scenario, a sub-category of analytic scenario, as explained below.

Analytic scenarios can be specialized. Let us start from bottom. Basic scenarios are represented by exactly one basic knowledge conversion. For example, a socialization conversion will convert tacit knowledge of one employee to tacit knowledge of another. Basic scenarios are specialisations of simple scenarios, which can be described by single general knowledge conversions. The next higher level of generality is a sequential chain of general knowledge conversions. Here, as an example, a step-wise knowledge development process of an employee may be modeled, where in each step the appropriate new knowledge from others will come in and be utilized. Chains of simple scenarios are one important sub-category of the general nets, which establish the category of analytic scenarios.

At least for simple cases, analytic scenarios can be supported by a rule-processing system based on a knowledge ontology, which has been built as representation of our knowledge and knowledge dynamics concept. A set of corresponding rules for addressing these scenarios and their representations has been developed. Therefore,

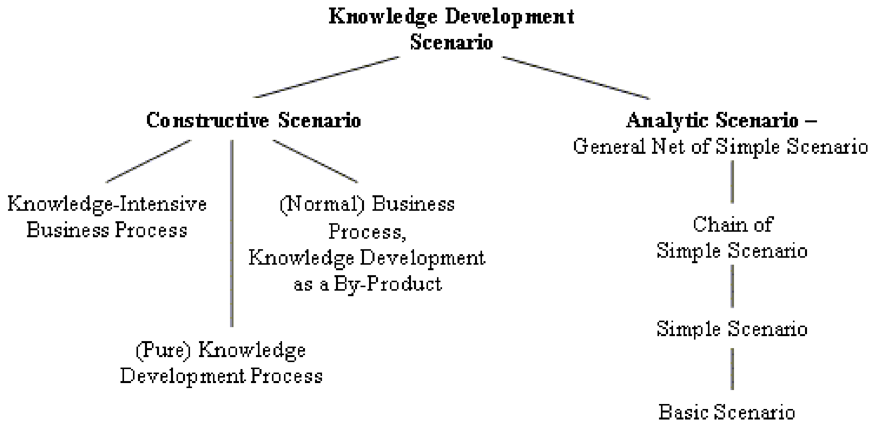

Fig. 4 Taxonomy of knowledge development scenarios

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possible solutions for those scenarios, i.e. filling the gaps in the scenarios, can be gained, see section VI for an example and [4] for a detailled description.

C. Taxonomy of Knowledge Development Scenarios

In this sub-section, the findings of the section are summarized and categorized in a taxonomy of knowledge development scenarios. This is a model-based taxonomy, because it relies heavily on the conceptual model of knowledge and knowledge development given in sections III and IV. Fig.4 depicts this taxonomy.

VI. Implementation Examples of Knowledge Development Scenarios

Two implementation examples, one out of the two main scenario categories each, are decribed in this section.

A. Example of a Constructive Scenario

As an example of constructive scenarios, a modeling approach for knowledge-intensive business processes with human interactions is described, which uses our knowledge development conception and represents a constructive knowledge development scenario.

We introduce an integrated model for knowledge management, which covers task-driven, knowledge-driven and human-driven processes in an organisation. It is based on seven very general entities (Process, People, Topic, Implicit, Explicit and External Knowledge, and Document) and the various interconnections between them. The model covers process-oriented approaches, reflects the human role in various forms (as individuals, groups, or knowledge communities plus the interaction between those) and the various types of knowledge with their mutual conversions. It is an extension of the model in [1] and reflects the new knowledge conception.

As notation for our model we propose an expressional extension of the Business Process Modeling Notation BPMN [6], which we call BPMN-KEC2 (KEC stands for knowledge, employees, and communities, 2 indicates the second version). BPMN is widely used for business process modeling, there exists a whole body of tools to support the visual modeling procedure, to integrate it in service-oriented architectures and to map models to execution environments for appropriate IT-support.

For a detailed description of BPMN-KEC2 see [3]. The most important notational objects may be categorized as objects for knowledge and information, for knowledge conversions, for associations between knowledge and persons, and for persons. Knowledge objects are tagged with type/kind information according to the two knowledge dimensions as introduced in Section III. The quality dimension of knowledge is not reflected in this approach. Quality characteristics of knowledge assets may be implicitly denoted in the knowledge name if necessary. General knowledge conversions are denoted with an elliptical symbol.

As an example, we model a business process for product renewal planning. The product is assumed to be knowledge-intensive and complex. The existing version of it should be possibly renewed by a new version. The overall process is modeled as sequence of four activities in BPMN notation: Propose product idea, define product characteristics, plan product development and finally decide on renewal. Here we will focus on the first one, which is really knowledge-intensive and requires human interactions. The expansion of this process using the BPMN-KEC2 notation is shown in Fig. 5. The main human actors are the product manager responsible for the product in the company, a knowledge community named *Expert Community*, and finally a product strategist. The expanded sub-process relies on two knowledge conversions. *Generate Product Idea* is a general and complex knowledge conversion, *Formulate Product Idea* a basic externalisation conversion. The main origins for *Generate Product Idea* are on the one side explicit knowledge on new technologies (of the propositional knowledge kind), conscious knowledge on actual relevant research themes, both available in a knowledge community named *Expert Community*. On the other side, knowledge on market trends and the product position of the existing product in the market is available at the product manager as conscious and explicit knowledge, respectively. Thirdly, the product strategist applies his internal knowledge (of the types conscious and tacit and of the strategic kind). Relevant information (*Market Information*) is available. Bringing this together via the knowledge conversion *Generate Product Idea* will end in a general product idea, being explicit knowledge associated to the product manager. This explicit knowledge now will be externalised in the second conversion to end up in external knowledge, the documented product idea.

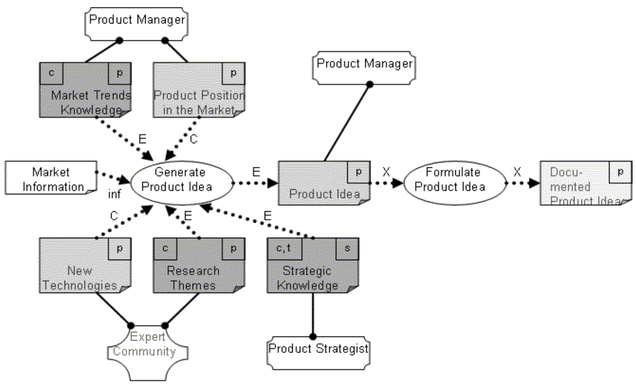

Fig. 5 Expanded process "Propose Product Idea"

B. Example of an Analytic Scenario

A knowledge ontology with reasoning support and a rule-processing system have been built. Fig. 6 shows the

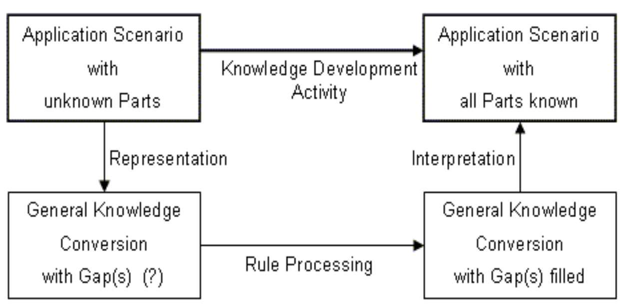

Fig. 6 Rule support of analytic scenarios

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main procedure for the handling of analytic scenarios. They are represented by general knowledge conversions with gap(s), processed with the help of the rule system, and finally interpreted as scenarios with all parts known. This work is already completed with respect to basic scenarios, the following shows a rule resolving a basic scenario with the gap at the source side, externalisation as known conversion and a known destination knowledge piece. The rule is formulated with the Semantic Web Rule Language (SWRL, see [14]):

```
Knowledge(?k2)  ^
Externalisation(?e) ^
hasDestination(?e, ?k2) ^
swrlx:makeOWLThing(?k1, ?k2)
→
Explicit_Knowledge(?k1) ^
hasSource(?e, ?k1)
```

Here, given knowledge k2 and the externalisation e, where k2 is the destination knowledge of conversion e, a new piece of knowledge (k1) is generated, which is of type explicit and is the source knowledge of conversion e.
As a result, the rule produces a new source knowledge of type explicit knowledge, which fills the gap in the basic scenario.

The next step, the support of simple scenarios is under development currently. Because of the rapidly increasing complexity of general knowledge conversions compared to basic ones, rule processing could no longer lead to unique solutions. Instead heuristics have to be introduced to support the scenario handling.

Support of chains or nets of simple scenarios will be straightforward then, once the simple ones can be handled.

VII. Summary and Conclusion

A new conception of knowledge and knowledge conversions is given, which serves as modeling basis for knowledge development in an enterprise. Investigation and classification of possible applications lead to a taxonomy of knowledge development scenarios. The main categories in this taxonomy are constructive and analytic scenarios. Derived from them important sub-categories are described. Two implementation examples are given. First, a modeling notation for knowledge-intensive business processes is introduced, which serves for constructive scenarios. Second, a semantic approach with rule processing is described, which can handle analytic scenarios.

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