XML-based Transformation of Business Process Models – Enabler for Collaborative Business Process Management

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Abstract: Interoperability of business process models provides a, if not the fundamental starting point for the development of an inter-organisational business process management. The integration of process models is, however, highly complex due to the heterogeneous use of modelling methods and tools and due to distributed modelling within collaborative networks. The paper deals with the problems of semantic and syntactic interoperability, the mapping of established on "new" methods, e.g. of EPC on BPMN, and the coupling of public and collaborative processes. We propose an adaptable solution in the form of a procedural model to reduce the complexity of the planning- and creation-tasks and to provide an example of how XML-based model transformation can enable integration on a conceptual level.

1 Collaborative Business Process Management

Looking at the added-value chain of enterprises, a change from an intra-organisational perspective – keeping value-creation within its own borders – towards an inter-organisational perspective – value-creation within a network of specialised firms – can be observed [Ka91]. The growing importance of cooperation is a result of globalization in combination with the disappearance of political borders and, above all, technological advances caused mainly by the Internet [SET00], [Sc02a]. Thus enterprises have to react to the raised innovation pressure and facilitate flexible collaboration on a global scale by aligning their business processes.

The **borderless enterprise** has been the subject of scientific discussion for years [PWR97], [Na86] and the collaborative production of goods and services has been established as a crucial factor in the consciousness of economic entities. Current approaches that address solutions to specific problems of dynamically interacting organisations are summarized under the term "**Collaborative Business (C-Business)**" [RS01]. C-Business describes the Internet-based, interlinked collaboration of all participants in an added-value network – from the raw material supplier to the end-consumer [SGZ03]. It allows a comprehensive information exchange not only between employees but also between departments and even between enterprises and encourages creative cooperation on all levels. Unlike former concepts, as e.g. E-Procurement, which focused only on small parts of the value chain, C-Business incorporates all stages of added value [SFZ03].

A key success factor in the future will be the ability of a company to plan, design, standardize and implement the way it reacts to (internal and external) business events and interacts with customers, suppliers, partners and competitors. From a conceptual point of view, business processes have proven to be the ideal design items in conjunction with the use of graphical methods and tools [Ch02], [Sc02b]. At the moment, a shift towards **collaborative processes** can be observed. The modelling and managing of these extended processes that span multiple organisations brings new challenges regarding the flexibility, decentralization and the support for **interoperability**[1]. The complexity rises considerably as a result of the numerous possibilities of interaction as well as the strategic, structural and corporate cultural differences between the partners. Coordinating the business partners turns out to be more difficult, especially because of the differing objectives and the lack of inherent organisational arrangements and behaviour guidelines as they exist within an enterprise [SBH00]. The allocation of performances and resources of the business partners, the determination of responsibilities for material and financial exchange relationships as well as the information and data exchange over interfaces have to be planned, arranged and "lived" together. Thus the demands on "**Collaborative Business Process Management (C-BPM)"** [SGZ03] increase significantly.

While the technological implementation [Li00] on the one hand and the lifecycle of cooperations [Li02] on the other hand have already been intensively researched, too little consideration has been given to the interconnecting management concepts. A rethinking from the pure technology-driven implementation or profit-driven business model discussion to an integrated view that spans from the conceptual level to the system blueprint is needed in order to reduce the inherent complexity.

The holistic and systematic planning and design of inter-organisational processes demands an architecture that offers a set of integrated methods from the business concept level up to the implementation into ICT-systems. A proposal for such an architecture is being developed by the project ArKoS [ZAH04]. Existing BPM methods and phase models were used as a foundation and had to be adapted to the specifications of collaborative scenarios. Especially because of its completeness of vision and its proven practicability, both in the scientific and the economic context, the "**ARIS House**" [Sc02b] is accepted as a generic framework for business process management and serves as a basis for further considerations. The ARIS House describes a business process, assigning equal importance to the questions of organisation, functionality and the required documentation. First, it isolates these views for separate treatment in order to reduce the complexity of the description field, but then all the relationships are restored using the Control View introduced for this purpose.

The three-tier framework follows the concept of "**business process excellence**" of Scheer [SB99], which consists of a concept to track a complete life-cycle model of busi-

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[1] Interoperability is seen in this context as the ability to exchange information in a collaborative environment and make use of it.

ness process management, including modelling, real-time control and monitoring of business processes. The first layer of the "**Architecture for Collaborative Business Process Management**" focuses on the "**Collaboration Strategy"**. In the centre of the second layer, the "**C-Business Process Engineering**", there are design, optimisation and controlling of both enterprise spanning and internal processes. The third layer, "**C-Business Execution**", deals with the (operational) implementation of business processes in value-added networks as well as their support through information and communication technologies.

The first findings of the conducted research within the project clearly show that the complexity of the planning- and design-task increases significantly compared to intra-organisational business process management and that the communication of results, mainly in form of process models as the key elements, is one, if not the crucial factor for the success of inter-organisational process management. Furthermore, the appropriate graphic representation of the results and user-friendly, intuitive tools that ensure the flawless connection of the different levels are of great importance in order to support the exchange of ideas and the reconciliation of interests between the different recipients within the network.

All this points out the need for the exchange of business process model data based on open standards to reduce complexity within C-BPM. The contribution of this paper to the overall problem of high complexity in collaborative environments is a procedural model for the transformation of established methods (representing private and public processes) onto "new" methods (representing collaboration processes) that enables the exchange of business process models. To do so, suitable transformation methods have to be developed. After section 2 gives an explains crucial problems which arise within the transformation of process models, section 3 outlines the state-of-the-art in related research and standards in business process modelling. The conceptual approach towards XML-based model transformation is presented in section 4.

2 Shortfalls in the Transformation of Business Process Models

Conducted research in the project ArKoS has shown that there is a set of problems within the scope of C-BPM that prevents efficient collaborative modelling [ZAH04]. The added complexity within planning- and design-tasks in collaborative environments mainly stems from two factors: the use of **heterogeneous modelling approaches and tools** and the **distribution of the modelling task** within collaborative networks.

The level of complexity escalates when trying to couple processes with one another in the development of a collaborative process model, as each network participant has their own "private" set of established methods (e.g. EPC, Petri-Net, UML Activity Diagram, BPMN) and tools (e.g. ARIS Toolset, VISIO, Rational Rose, eMagim, Metis) in use. Due to a lack of common interfaces and mapping-methods, neither can the tools interact with each other nor can the methods be transformed into one another. This crucial question of interoperability is also addressed by the European Union within the research projects UEML and INTEROP.[2] The distributed modelling approach towards the collaborative process model requires significantly more coordination than in an intra-organisational case. Insecurity, e.g. by the use of open networks, and the question of trust [Ra03] intensify the problems of coordination.

Despite the enormous networking potential described in section 1, enterprises are generally not willing to reveal critical knowledge about the way they conduct business to collaboration partners, which could otherwise lead to competitive disadvantages. This means that they hide knowledge about their internal business processes. To extract information relevant to the network from these "**private processes**", a collaboration-specific view is generated, providing all or at least some information (**white-box**) or in a **black-box** manner with no indications about their realization. In this case, only the interfaces of the private process are described. This view, which is a publicly visible abstraction of a private process, is also referred to as "**abstract process**" [Fr04] or "**public process**". The common aggregated process, visible to all networking partners, is referred to as global or **"collaborative process".** For the modelling of private processes on the one hand, well established and approved modelling techniques such as EPC are mostly used in order to reduce investment risk and to stick to procedures that have proven to be successful. The collaborative process on the other hand is often expressed in standardized, "new" approaches, e.g. the BPMN. Hence private process models must be protected against external insights but at the same time integrated into the whole collaborative process for the extended approach of C-BPM. Thus, the need for mapping "new" with established methods arises. Figure 1 visualizes the concept of private and collaborative processes with underlying modelling and transformation methods.

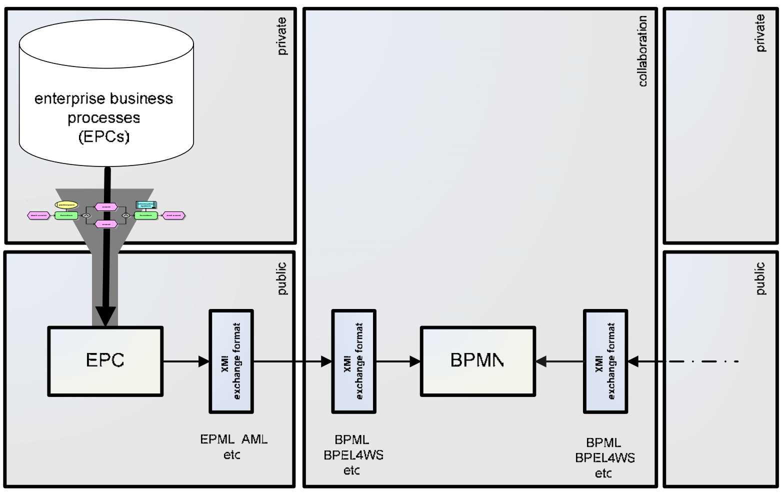

Fig. 1. C-BPM schematization of business process model use

[2] See http://www.ueml.org and http://www.interop-noe.org for further information.

As a conclusion, adequate transformation concepts, methods and tools have to be developed based on the use of open standards to guarantee interoperability. The solution must be addressed on the semantic and the syntactic level: To obtain syntactic integration, the mapping of method meta-models with object-relations is proposed in section 4. Moreover, the more difficult problem of semantic integration[3] is also addressed and structured.

3 Concepts on Business Process Modelling

This section presents concepts and standards used for the mapping of heterogeneous methods and their XML-based exchange needed for the presented C-BPM approach (cf. Figure 1). The following methods were chosen for the example provided in the next section as these approaches adequately represent the process modelling requirements for third generation BPM:

EPC: The **Event-driven Process Chain (EPC)** was developed in 1992 at the Institute for Information Systems in Saarbruecken in cooperation with SAP AG [KNS92]. EPC-models are central elements of the BPM for most of the TOP 100 European enterprises also because of its use in the SAP R/3 reference model of SAP AG and the ARIS Toolset of IDS Scheer AG [Sc02c]. Enterprises model their process data as EPC-models in order to plan, design, simulate and control private enterprise processes. The method represents an expansion of Petri-Nets by integrating logical operators such as AND, OR and XOR [Sc97]. The EPC describes processes by the use of alternating functions and events as time-referring state changes. Arcs or directional angles connect functions and events [Ke00]. The **extended EPC (eEPC)** introduced further elements such as process participants or data and information systems (cf. Figure 2). The EPC is a core part of the ARIS-framework and combines the different views into the description of enterprises and information systems in the control view at a conceptual level.

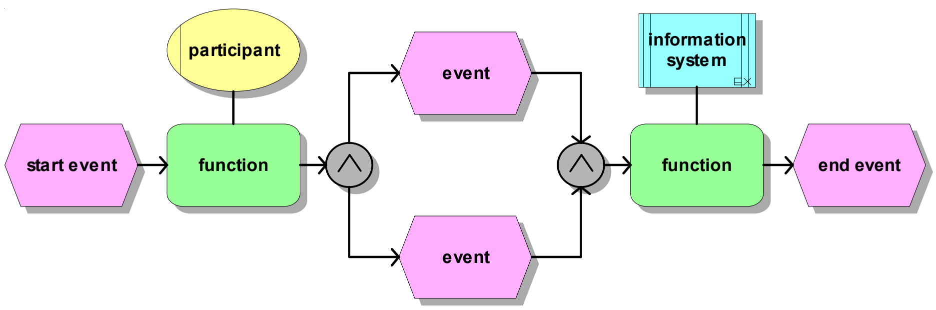

Fig. 2. Extended EPC model

[3] Semantic integration is seen in this context as sharing knowledge about the meaning of objects within networks.

EPML: The **EPC Markup Language (EPML)** introduced by Mendling and Nuettgens in 2002 offers a standardized approach towards the horizontal and vertical integration of models [MN04]. An EPML document represents semi-formal business process information of an EPC in a machine-readable XML-format. As the EPML was introduced with the aim to accomplish readability, extensibility, tool orientation and syntactic correctness [MN03], it covers a wide set of requirements of XML-based markup languages. The current specification of EPML is able to represent EPC-information concerning events, functions, logical operators, arcs, participants, information systems, data fields, business perspectives and additional, model-specific graphical information.

BPMN: The **Business Process Modeling Notation (BPMN)** specification developed by the Business Process Management Initiative (BPMI)[4] provides a standardized, graphical language for the visualization of business processes on the conceptual, near-business level [OR03]. Furthermore, **vertical integration** is facilitated by mapping to executable XML-languages – as for instance **BPEL4WS** (Business Process Execution Language for Web Services) or **BPML** (Business Process Modeling Language) [Wh04] at the C-Business Execution level of the ArKoS-Architecture. To model business processes, BPMN offers so-called Business Process Diagrams (BPDs) [OR03]. Processes are represented by the use of events and activities. Gateways allow splitting and joining of processes. Sequence flows are modelled as arcs. As shown in Figure 3, organisational responsibility or process actors can be visualized by pools (typically companies) and swimlanes (typically divisions). BPMN also allows an explicit visualization of inter-organisational aspects, e.g. flows that are modelled as message flows between pools.

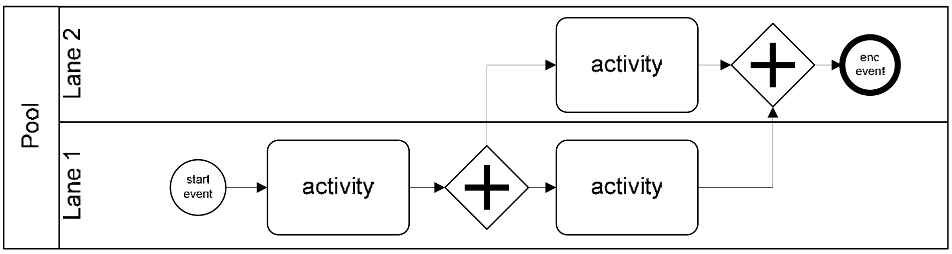

Fig. 3. BPMN model

BPML: The development of the **Business Process Modeling Language (BPML) –** another standard of the BPMI – was initiated in 2000. Meanwhile, more than 80 companies are working on this open specification for the management of business processes [HL04]. The XML-based approach aims at the modelling of executable business processes by using different activity types, process hierarchies and further definitions [Ar02]. In the context of the ARIS House, the presented semi-formal graphical and formal XML-based non-graphical process representations belong to the control view.

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[4] See http://www.bpmi.org for further information.

4 XML-based Approach for Model Transformation

The following section presents an approach to the transformation of methods for business process modelling. The procedural model, consisting of six steps, can be applied to an unidirectional, horizontal mapping of modelling methods of which XML-representations exist.

An example of how XML-based model transformation can enable integration on a conceptual level is provided in which we focus on the transformation of business process data represented by established modelling methods into standardized inter-organisational methods. The content of business process models is transferred over different layers of representation: semi-formal graphical process models as the central element of C-BPM and formal textual XML documents as machine-comprehensible supporting mediums. The transformation from graphical models to XML-data is not addressed in detail within this transformation approach. Following the established economic behaviour, private business processes are modelled in the **EPC-notation**. Based on these models, a public view – still in the same notation – is generated, containing all relevant process information for the specific collaboration (cf. section 2). The resulting process models are subsequently transformed into a collaboration-centric exchange format for which we choose the **BPMN,** and are merged with the partners' public abstractions. Our example only deals with this step, i.e. the transformation in a more narrow sense. After the transformation the process can be integrated with other parts of the collaborative process and a C-Business landscape can be created.

4.1 Step one: Agreement on Meta-Models

The first step towards the transformation from one method to another is to get a collaboration-wide agreement on the meta-models of the process-modelling methods used by the partners. The meta-models describe the result and the structure of the modelling method appliance [GU94]. These meta-models are documented for a majority of methods,[5] but are often altered or enhanced by company-specific definitions. The common meta-model for the collaborative business process has to be defined manually – due to its creative nature –by modelling experts of all partners. The resulting models serve to harmonize the vocabulary of the constructs used in the meta-model (cf. section 4.2) and are a prerequisite for extracting mapping rules, which is done by defining corresponding process-objects (cf. section 4.3).

4.2 Step two: Unification of Terms

Second, the usage of terms has to be unified, in order to reach a certain degree of **semantic interoperability –** by implementing semantic comparability and correctness [BRS95] – and to achieve a high model quality. By agreeing on a meta-model the common understanding among collaboration partners is achieved. Naming conflicts of processes and

[5] See for example [Ro96a].

process objects caused by synonyms and homonyms are avoided [Ro96b]. The unified vocabulary, stored in a central repository, the so-called **term-specific convention repository**, contains descriptions of all relevant private methods and models and can be accessed by all partners [FSS00]. In the repository, elements cannot be tracked to the originating partner in order to protect their private knowledge. Hence the definition of a unified vocabulary brings forward the application of standardized language elements in process models.

The generation of the vocabulary can be simplified by the use of cooperation-specific reference models[6] as a complexity-reducing measure. **Industry- and/or function-specific reference models**, e.g. the Supply Chain Operations Reference Model (SCOR) which defines core supply chain processes and process objects in certain detail [BR03], facilitate a common understanding. The use of **industry-ontologies** which define important terms and their interrelations [WW02] additionally helps in this operation.

4.3 Step three: Mapping of Meta-Models

The third step consists in the method meta-model mapping. The element- and the structuretypes of one method are related manually to one or more corresponding types of another method (cf. Table 1). Double arrows stand for unambiguous, bi-directional relations between corresponding model types, single arrows represent ambiguity.

EPC type	**uni- /bi-directional relation**	**BPMN type**
function	←→	activity
aggregated function	←→	subprocess
event	←(→)	start event
event	←(→)	intermediate event
...	...	...

Table 1. selected type relations between different modelling methods

If a one-to-one mapping is not possible due to the lack of simple relations, an exception handling must be established. EPC events, e.g., do not vary in a syntactical way, a starting EPC event must however be identified and mapped to a BPMN start event (cf. Table 2). The need for such exception handling is visualized in Table 1 by brackets. Transformation rules are extracted from these relations. Event rules may proceed automatically.

Exception classes
▪ automatic check: current event (EPC) = starting event (EPC)   o automatic mapping: current event (EPC) = start event (BPMN) ▪ ...

Table 2. exception classes for event mapping

[6] In this context, a reference model is seen as an abstraction of individual cases and representation of standardized real world scenarios [FL03].

As a further example of exception handling, EPC participants and information systems also need a corresponding representation in BPMN models. Here, the usage of pools and lanes can be interpreted for transfer of the EPC model information. The kind of mapping finally depends on what is aimed at with the collaborative process model.

With the use of XML-data formats to exchange process model data, an **eXtendable Stylesheet Language Transformation** (XSLT) script which transforms XML-documents from one format into another [Bo04] is implemented within the ArKoS-project (cf. section 5) to get an automatic, computer-based transformation. The mapping and exception rules presented here serve the derivation of the appropriate XSLT rules.

4.4 Step four: Model-Export

Now the process models which should be made publicly visible or, in other words, exchanged within the network, are exported to a standardized exchange format – in this example from EPC to EPML. Model data is represented in a formal way, which can be understood and processed by computers. The following figure shows part of the formal EPML-representation of the process that is subsequently transformed into BPMN.

```
<?xml version="1.0" encoding="UTF-8"?>
...
<definition defId="0" type="relationshipType">
    <name>responsible for</name>
</definition>
<directory name="Root">
<epc epcId="1" name="business_process">
           <application id="1">
                  <name>application</name>
                  <description>application</description>
                  <graphics>...</graphics>
           </application>
           <relation id ="15" defRef="1" from="1"
                         to="6"/>
           <event id="2">
                  <name>start_event</name>
                  <description>start_event</description>
                  <graphics>...</graphics>
           </event>
           <arc id="16">
                  <flow source="2" target="5"/>
                  <graphics/>
           </arc>
           <function id="3">
                  <name>function_one</name>
                  <description>function_one</description>
                  <graphics>...</graphics>
           </function>
    ...
</epc>
</directory>
</epml:epml>
```

Fig. 5. transformation result of EPC into EPML

4.5 Step five: XML-Transformation

After the successful export, the mapping between two XML-methods is executed in a fifth step. Based on the rules predefined in step three, the XML-method is transformed into another **XML-based process markup-language** as – for instance – PNML for Petri-Nets or BPML for BPMN. In our example, the BPML is used as the target method because it offers a direct mapping to the BPMN [OR03]. The results of the transformation are shown in Figure 7.

Due to a lack of specifications of process actors in BPML, a code extension is introduced which allows the mapping of tasks and functions of a process to corresponding responsibilities, accordingly. The extension enables the transfer of data into BPML which is originally not possible in this XML-format. A hierarchical structure of **process actors** also has to be inserted manually into the transformation rules and related to a pool or a lane corresponding to its position in the hierarchy. Hence we can conclude that there is a need for additional code which is inserted into the `<bpml:documentation>`-part of the BPML-description [Ar02]. The code specifies exact relations of tasks or functions to certain process actors as superior pools or inferior lanes (cf. Figure 6). To extract the essential information of which task is assigned to which process actor, one has to analyse the `<relation/>`-tags of the EPML document.

Additional **graphical process model information** may also be stored in the `<bpml:documentation>`-part. This data has to be defined manually within the transformation process by modelling experts due to the lack of standardized definitions.

```
<bpml:pool
    name="department xy">
            <bpml:lane name="application"
                          activity="function_one" />
            <bpml:lane name="application"
                          activity="function_two" />
              ...
            <bpml:lane name="Mr XY"
                          activity="function_four" />
              ...
</bpml:pool>
```

Fig. 6. BPML extension for the specification of process actors

Furthermore, the **task sequence** has to be extracted from the EPML-document by the analysis of relations between events (`<event/>`), arc relations (`<arc/>`) and functions (`<function/>`) and has to be transformed into the corresponding BPML-code. Events are completely removed except of the starting event. The sequence of EPML functions is transformed to the sequential `<bpml:sequence>`-form [Ar02] with the EPC starting event triggering the BPML sequence. Figure 7 presents the result of this transformation.

```
<bpml:process name="business_process">
    <bpml:documentation>
    <!-- code extension -->
           <!-- process actor -->
                  <bpml:pool
                         name="department xy">
                         <bpml:lane name="application"
                         activity="function_one" />
                         <bpml:lane name="application"
                         activity="function_two" />
                           ...
                         <bpml:lane name="Mr XY"
                         activity="function_four" />
                           ...
                  </bpml:pool>
           <!-- /process actor -->
    <!--/ code extension -->
    </bpml:documentation>
    <bpml:sequence>
           <bpml:event activity="function_one"
                  name="start_event"/>
           <bpml:action name="function_one"
                  operation="request"/>
           <bpml:action name="function_two"/>
           <bpml:action name="function_three"/>
           ...
    </bpml:sequence>
</bpml:process>
```

Fig. 7. transformation result of EPML into BPML

4.6 Step six: Import of the Process Model

For the final step towards visualizing the collaborative process, the formal process modelling method (in our example BPML) has to be transformed back into a semi-formal, graphical model representation (BPMN). This step can be completely automated as mapping rules exist. However, the code extensions included (cf. section 4.5), e.g. the mapping onto pools and lanes, have to be formulated in corresponding rules and will be included as an import feature in the tool prototype.

5 Results and Conclusion

The approach presented in this paper deals with a set of deficiencies as specified in section 2. In particular the paper provides an approach to:

- solving the problem of **heterogeneity in business process modelling** by presenting an adaptable procedural model to gain syntactic model interoperability. This is achieved by the local mapping of corresponding objects on a meta-level between collaborating enterprises. Furthermore, a step towards semantic model interoperability is described by the use of a conceptual description of a term-unifying repository.
- considering current research efforts towards **XML-based representations of business process models**, as – for instance – it is done with EPML and BPML.

- taking care of forward-looking **standardization approaches**, as they were presented by the BPMN – and consider at the same time well-known, established modelling techniques as the EPC to decrease investment risk for enterprises by merging "new" with established models.

- describing business model integration efforts on a **conceptual level** to get an open reference solution independent of any fixed connection to certain methods. The approach may be adapted to other modelling methods, such as Petri-Nets or Activity Diagrams as far as a corresponding XML-representation is available.

The paper does not claim completeness in terms of semantic integration and syntactic mapping covered due to the lack of an adequate formal XML-representation of BPMN and further essential research. It focuses rather on a general procedure model that shows how transformation in a unidirectional way can be conducted in order to facilitate the exchange of process models in heterogeneous environments, i.e. the transformation of public processes to collaborative processes by mapping the respective methods. The proposed concept delivers an integration of business process models independent of the modelling methods used. Ambiguity or other textual model defects may be avoided, which leads to a significant reduction in complexity and enables a more efficient planning- and design-task concerning BPM.

The greatest demand for further research can be seen in the need for a better XML-based representation of standardized modelling techniques. Related approaches as – for instance – XML Metadata Interchange (XMI) [OM03] have to be analyzed to gain possible synergies for this procedural model. Another aspect that requires further research is the use of supporting tools that ease the task of exchanging process models between different enterprises, i.e. to distinguish between private and public knowledge and to automate all possible mapping tasks by adequate rule-based systems. The survey on transformation between different modelling concepts must be addressed in further research on a methodological layer. In this regard the procedural model has to be validated for further relevant modelling concepts as Petri-Nets or UML Activity Diagrams. Fundamental ideas may certainly be adopted from this approach because of its general orientation. Furthermore, the vertical integration of process information through transformation and mapping of business concepts into ICT-interpretable, formal process specifications [OR03] is another field for further research.

The concept presented in this paper is discussed within the background of the research project "**Architecture for Collaborative Scenarios (ArKoS)**"[7] [ZAH04] funded by the German Federal Ministry of Education and Research (BMBF). A prototype of the presented integration approach is being implemented at the moment and will be further improved in subsequent project activities by formalisation of additional automated transformation rules and other features described in this paper.

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[7] See http://www.arkos.info for further information.

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