Enabling dynamic networks using an architecture for collaborative scenarios

T. Theling, J. Zwicker & P. Loos
ISYM – Information Systems & Management, Johannes Gutenberg University, Mainz, Germany

O. Adam & A. Hofer
Institute for Information Systems at the German Research Center for Artificial Intelligence (DFKI), Saarbruecken, Germany

ABSTRACT: Collaborative business requires integration of involved enterprises' information systems. Characteristics of project networks like changing business partners or raising exceptions lead to dynamic structures within collaborations. This is a special challenge for a common IT infrastructure. This paper presents an architecture for dynamic cross-enterprise processes' planning, execution, and controlling on a conceptual level. In a first step, a distinction of local and global knowledge is provided in order to establish a Collaborative Business Process Management Lifecycle. Afterwards, requirements for a collaboration-supporting architecture are briefly upraised and the resulting architecture is presented. In a last step, the architecture is adopted to special requirements of AEC. Domain-specific data like placing units and specifications are introduced and the process of tender, placing and accounting is depicted within the architecture. Therefore, different parts of the architecture are involved.

1 INTRODUCTION

1.1 Motivation and Structure

Innovation pressure arises in interaction relations like supply chains and in networks with complementary core competence partners. The opening of organizational borders is no longer regarded as a necessary evil, but rather as a chance with strategic importance. Therefore inter-organizational applications and the transfer of business process management aims into collaborative IT systems are considered.

This paper presents an architecture for dynamic cross-enterprise processes' planning, execution, and controlling on a conceptual level. After an overview about related work, chapter 2 introduces a distinction of local and global knowledge in order to establish a business process management lifecycle in chapter 3. Chapter 4 presents an integrative architecture, which enhances appropriable concepts of workflow management and business process management to enable collaborative business integration on multiple levels. Chapter 5 shows a possible application within the domain of Architecture, Engineering & Construction (AEC), while chapter 6 gives a summary and an overview of future work.

1.2 Related Work

Collaborative Business is discussed from several perspectives. Many authors describe reasons for collaborations and establish several economical theories like transaction costs (Coase 1938; Williamson 1995), the market-based view proposing strategic groups to evaluate cooperations' effects on the market (Caves & Porter 1977), or the resource-based view emphasizing competencies of corporations (Hamel & Prahalad 1990). The coopetition approach integrates several aspects of these theories (Brandenburger & Nalebuff 1995).

Concepts of borderless enterprises (Picot et al. 1999) have been discussed for years and the collaborative production of goods and services has been established. Current approaches addressing solutions to specific problems of dynamically interacting organizations are summarized under the term "*Business Integration*"; the field of investigation is referred to as *"Collaborative Business (C-Business)"*. C-Business describes the Internet-based interlinked collaboration of all participants in an value added network (Zang et al. 2004). It considers organizational aspects and assimilates existing concepts of workflow management and business process management (BPM) frameworks (Eom & Lee 1999; Evaristo & Munkvold 2000; Hollingsworth 1995; Rittenbruch et al. 1998; Scheer 1999; van der Aalst 2002; Wild et al. 2003). Regarding a technical support for this topic, Web Services and Service Oriented Architecture (SOA) are discussed (Alonso et al. 2004; Patankar 2003).

Many articles and contributions discuss architectural approaches which support collaborative BPM.

Numerous requirements concern trust within collaborations (De Santis et al. 2003; Gronau 2003; Megaache et al. 2000; Whitescarver et al. 1997), so e. g. secure transactions or role-based computing. Another aspect is flexibility which enables easy application integration, self-organization of IT-architectures or scalability of software systems (Gronau 2003; Patankar 2003). Reusability of components (Blake 2000; Patankar 2003) and integration of used business modeling languages (Gronau 2003) are further requirements. Whitescarver et al. upraise further requirements of different frameworks like socio-psychological collaboration, organization and communication, user interfaces, network infrastructure, and meta tools (Whitescarver et al. 1997).

A possible approach to fulfill some of these requirements is using portals with unique user interfaces. Portals can integrate tools for teamwork and project management or for collaborative process execution. They provide access to unstructured information like documents or charts as well as to structured information like transaction data, analyses and evaluations. Many approaches have not been accepted within AEC.

2 VIEWS ON BUSINESS PROCESS MODELS

The different views onto business process models are based on the Architecture for Integrated Information Systems (ARIS) and divide it into a vertical axis of *global knowledge* (available for all network participants) of all collaboration partners and a horizontal axis of *local knowledge* (available for two cooperating partners) of the single participants (cf. Fig. 1). The organisation view and the output view are global knowledge because a goal-oriented collaboration is impossible without them.

At the time the interaction occurs between two partners, local knowledge is shared (bilaterally) between the partners, i. e. additional information, like data structures and semantics, is exchanged. Updates of the local knowledge do not influence the network as network knowledge has to be available for all partners. This information is stored in the description of interfaces between the process modules of the partners. Changes in the global network knowledge and as a consequence changes in the output and organization view have to be accessible to all partners immediately, for example if a company leaves the network or if a product or service is no longer available within the network.

Global and local knowledge merge gradually in the step-by-step development of C-Business process engineering. Following the distinction between global and local knowledge, a language is needed for the exchange of these knowledge fragments. Because the necessary detail functions and data schemes of the respective enterprise are determined in the data and the function view, these are treated from a micro perspective. They are characterized by an intensive internal interdependence, whereas externally a standardized encapsulation has to be provided. Interfaces of the data and function views to other network participants become visible in the process view in form of attribute correlations to process modules and concern the technological field of the cooperation during the realisation much more intensely than the conceptual one.

This technique enables the generation of **public** (visible to network partners) and **private** (enterprise-internal) **views** and levels of detail for management, process owner and IT-experts out of a C-Business model.

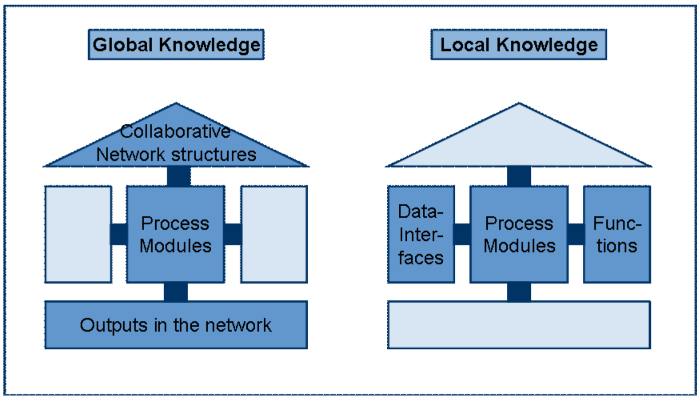

Figure 1. Global and local knowledge in value-added networks

Enterprise spanning business processes are not planned in detail at the strategic level, but are designed as concentrated, high-level process modules. Thus, they combine the public knowledge about the collaborative processes that is shared by all participants. C-Business scenario-diagrams that are used e. g. by SAP Ltd. for the description of my-SAP.com collaboration scenarios, aim at the representation of the cooperation of different enterprises and participants by means of an easily understandable method and the documentation of the value-added potentials resulting from it. The responsibility for each process step, indicated by swimlanes, is of central importance to the determination of the scenario. This method is integrated into the ARIS concept and combined with methods of (classical) business process and data modeling used at the C-Business Process Engineering layer.

The question of core competences in the enterprises is directly associated with the question which processes remain in the enterprise and which are supposed to be assigned to partner enterprises or collaboratively operated.

3 COLLABORATIVE BUSINESS PROCESS MANAGEMENT LIFECYCLE

The lifecycle model presented in this section serves as a manual for the process-oriented setting-up and operation of cooperations. Using a consistent phase model and standardized modeling methods increases transparency and structuring of cooperations and creates a basis for communication between participants, including management that lays down strategies, process-owners in the departments and IT-experts that integrate the different application systems. The model is a fusion of classic phase models with lifecycle models of virtual enterprises.

Protecting internal know-how is of paramount importance to the network participants, even though the business process knowledge has to be used jointly. Following the view concept presented in chapter 2, the lifecycle alternates between phases that focus on global and on local issues in order to reach a coherent solution (cf. Fig. 2).

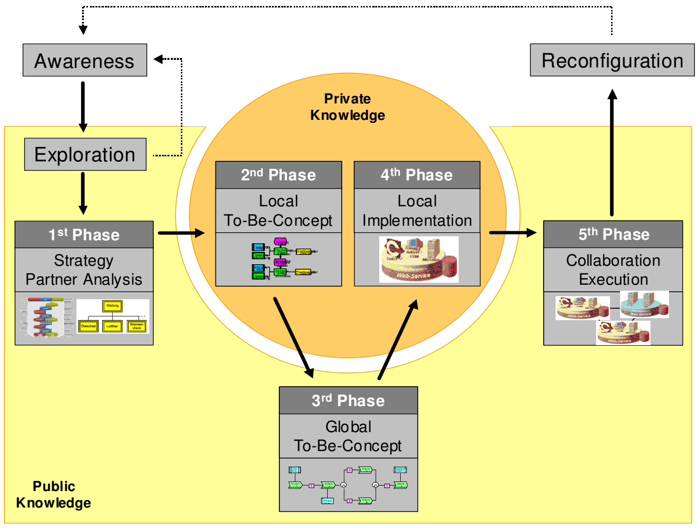

Figure 2. Collaborative Business Process Management Lifecycle

3.1 *Pre-phase and reconfiguration*

Prior to the use of the architecture is the *awareness* of one or more enterprises that they can profit by collaboration with complementary core competence partners. The decision if and with which enterprises a C-Business scenario should be implemented is taken by every single enterprise individually and rationally; for this reason it depends highly on the expected economical profit of the individual partner. In this model, it is assumed, that a set of potential network participants is given.

After conducting the cooperation, companies regroup or split and *reconfigurate* themselves. The lifecycle returns to its starting position “awareness”.

3.2 *Main-phases*

In the first phase *Strategy Partner Analysis* or formation phase, also referred to as initiation and agreement of the enterprise network, the collaboration partners are determined by the shared goals of the collaboration and the aspired win-win situation of all partners. The joint aims of the collaboration have to be defined as synthesis of the individual aims.

To facilitate the collaborative service or product delivery, graphical methods, like product models, are used in this stage for the determination of a common service or product bundle. They simplify and put the often implicit objectives into concrete terms. In addition to the characteristic features of a service or a product over its entire lifecycle, the organizational units participating in the production are contained in a product model. By means of product trees, enterprises can conceal detailed service descriptions in an internal view that puts special focus on the organizational aspects of the product offered by the partners. In an external view they just provide the information required for the configuration of the common service bundle in form of product bundle models.

Having completed the strategy finding, in the second phase, *Local To-Be-Concept*, an existing or a new (local) as-is model and the (global) to-be concepts are compared. According to predefined conditions about collective product creation, intra-organizational business processes can be derived. Each partner considers his part in the inter-enterprise process. Starting with process modeling and optimization over process controlling up to implementation, the processes involved are aligned with the requirements of the collaborative scenario agreed on in the former phase.

In the third phase, *Global To-Be-Concept,* coordinated public parts are allocated over the network, establishing a collective to-be concept. Every partner is able to connect his own private model with every other public process model. Every partner gains his partial view of the collaborative process, so a virtual process chain of the whole collaboration is designed. The Business Process Execution Language (BPEL) can be considered as an appropriate exchange-language. Global knowledge is described in a public interface, which can be provided by a BPMN representation. The public processes as well as the message formats and contents can be formally defined by B2B protocols like RosettaNet or ebXML. Furthermore the semantic combination of models of the different partners is necessary. As long as ontology-based approaches don’t reach a productive state this combination process is a manual action.

The integrated collaborative business process model enables all partners to configure their application systems locally in a fourth phase called *Local Implementation*. Reference systems for interfaces are provided by interface definitions of the collective to-be concept.

Now every partner is prepared for the execution of interactions within the collaborative framework. That is the transition to the fifth phase *Collaboration Execution*. Based on bilateral bases interacting information systems are able to communicate by using the standardized protocols and interfaces. The transactions are arranged and executed. The aim of this phase is to support collaboration through the appropriate use of ICT. That requires primarily the configuration of interfaces and the implementation of interorganizational workflows; at the same time the permanent monitoring and adaption of the collaboration, based on business ratio defined in the conception phase, must be assured.

In order to automate inter-organizational processes, the conceptual models are transformed into formal models that are used as configuration data for the orchestration of business objects. The applications of the partners have to communicate bilaterally to negotiate the interface specifications based on the formal models. The local knowledge is generated by this negotiation for a certain situation. After this collaboration task has ended, no updates of configuration changes etc. are reported to any other party except at the time when a new direct interaction occurs (Zang et al. 2004).

4 ARCHITECTURE FOR MANAGING COLLABORATIVE BUSINESSES

4.1 *Requirements*

Within the research project "ArKoS – Architektur kollaborativer Szenarien", a questioning of AEC experts regarding architecture requirements has been performed and led to following results: Regarding the management of collaborative business processes, preliminary planning processes of an AEC project (build time, existing of lifecycle's Pre-phase and phase 1-4) and controlling of actual running processes (run time, lifecycle's phase 5) have to be supported. This concerns analysis, simulation and optimization of business processes and collaboration structures. Therefore predefined ratios must be available, which requires a data exchange between monitoring tools and different operational IT systems.

Further on, arrangement and configuration of business processes and collaboration structures must be supported. Therefore various modeling methods have to be taken into account. At first, various corporations within the collaboration may use different modeling notations. At second, different abstraction levels of models exist, which leads e. g. to semi-formal models like event-driven process chains on an abstract level, while formal models like Petri nets may be used on a detailed level.

Another aspect is to keep business secrets of individual collaboration partners. This is realized by the presented distinction of global process knowledge from local process knowledge (cf. chapter 2).

A further requirement is to enable mobile access to various data. New mobile devices have to be integrated into the architecture.

4.2 *Architecture's Concept*

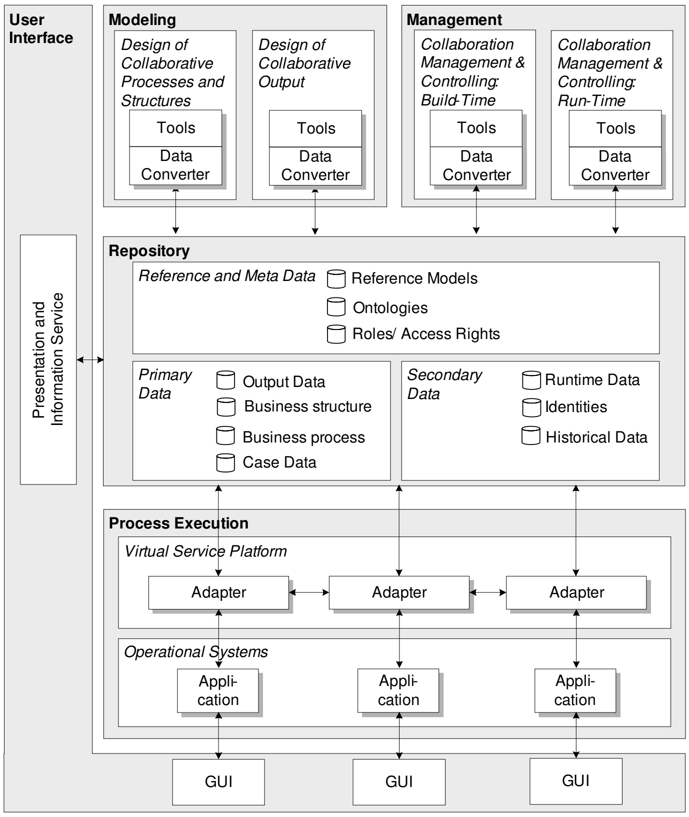

Figure 3. Architecture for Collaborative Scenarios

Based on the explained requirements, figure 3 depicts an architecture which supports collaborative business processes. It considers organizational aspects and integrates existing concepts for workflow and business process management. Relationships and components of Scheer's ARIS – House of Business Engineering (HOBE) as well as workflow management and business process management architectures are included (Hollingsworth 1995; van der Aalst 2002). Basic information for the process execution is visualized in business process models, output models, and organization models. These are created by modeling tools and stored in a distributed repository. Depending on process- and organization models, the virtual service platform executes processes and integrates different operational systems of the collaboration partners. The following sections describe components and characteristics of the architecture.

4.3 Repository

The architecture is realized upon a physical distributed repository managing all data. It enables business process management, common work on the underlying models, and cross-enterprise process execution. Individual knowledge of each partner is stored within decentralized parts of the repository. A logical centralization of the repository represents knowledge of the overall network.

Reference and meta data comprise information, which provide a basis for the design of process models as well as organizational models and create a common conceptual understanding: *Reference models* support the construction of individual models and improve the design of specific organizational structures and processes of the enterprise network (Fettke & Loos 2003; Mertins & Bernus 1998). *Ontologies* are able to unify differing vocabulary of concepts and meanings regarding the contents and semantics of models (Gamper et al. 1999; Kishore et al. 2004). They are formal conceptual systems of a domain, which obtain a knowledge transfer between applications and users. Within the architecture, ontologies are relevant for integration of different language formats between used applications. For the design of models they establish a common conceptual understanding of modeled issues. *Roles* are parts of the security concept of the architecture and define templates for description of economical requirements on persons within the network. A role bundles access rights on resources as well as data of the repository and can be assigned to particular persons, e. g. due to the enterprise affiliation or the workplace function (Edwards 1996).

Following the distinction of primary and secondary business functions in a value chain (Porter 1985), also the used data can be distinguished into primary and secondary data.

Primary data supports the operational realization of business processes and the primary purpose of the architecture: *Output data* provide descriptions of the outputs as results of executing collaborative business processes (Scheer 1999). *Business process data* obtain process models of the value-added network. Local processes are intra-organizational processes of particular network enterprises, which belong completely to functions, roles and resources within the enterprises, though they have interfaces to the enterprise-external processes and resources. Global processes form the process structure of the overall network by aggregating the local processes at corresponding interfaces. *Business structure data* contain the organizational structural model of the value-added network. Analogue to the process data, they can be distinguished into global and local structural models. Global structural models show the relationship structure of enterprises in the value-added network, whereas the local models represent the intra-organizational structures. *Case data* are, on the one hand, task-oriented resource data of the value-added network, which pass through the processes and will be processed to a stand-alone product (Hollingsworth 1995), e. g. documents or technical drawings. On the other hand, business data describe the task and network itself. Like the network, they can continually change. Examples are data about partner enterprises and their collaborations.

Secondary data stand orthogonally to business process management and embrace recording data or phase-overlapping data for supporting the process management: Historical data and runtime data are recording data, which comprise defined execution data and possible exceptions due to disturbance of process execution. *Historical data* are about executed or former processes, whereas *runtime data* record information about the current running processes of the value-added net. Both the historical data and the runtime data serve primarily the Collaboration Management and Controlling (CMC). Besides the aforementioned roles, *identities* are basic elements for access control on data of the repository.

4.4 Modeling

The Process and Structure Design (modeling of the value-added net) is performed by business analysts of the network enterprises in the role of a designer. They use appropriated tools, which are de-centrally available, e. g. tools for graphical visualization and modeling. The created models are stored in the repository. Modeling comprises the design of global and local models, whereas business secrets have to be kept by assigning roles and access rights. Reference models can be used, which have to be loaded from the repository into the modeling tools. Furthermore, ontologies can be used for consistent semantic modeling.

The design of collaborative output allows creating basis data about the collaboration's organization and global processes. Furthermore it is also used for operational tasks like cost calculation, requests for quotation or accounting. Output can be described in two different ways: in heterarchical networks the collaboration partners describe the output in common with each other, in focal networks the output can be described by a central scheduler.

All data and models are stored in repository-wide unique data formats. By using converters different software can be integrated, although it does not support a central data standard. In particular the data formats of the process- and organization-models have to fulfill several requirements: on the one hand different modeling tools with different modeling languages can be used, on the other hand collaborative-wide and enterprise-intern models may use different modeling languages. To store the models in a standardized format, we suggest BPEL (Andrews et al. 2003), which joins several characteristics of preceding standardizing projects. BPEL also is an advantage for the suggested architecture because many software vendors prepare their systems for using BPEL.

4.5 Collaboration Management & Controlling

Collaboration Management & Controlling (CMC) is distinguished into Build-time-CMC and Run-time-CMC. Build-time-CMC includes early life-cycle-phases (strategy and partner analysis, local to-be-concept, global to-be-concept, local implementation), while Run-time-CMC encompasses the phase "Collaboration Execution" and the reconfiguration of collaborations. Following the distinction into a processual and an organizational view of collaborations, the methods of CMC are divided into process-oriented and organization-oriented tasks.

Organizational tasks of *Build-time-CMC* are for example portfolio analysis, due diligence or boundary management for collaboration-, enterprise- and department-borders. Concerning the processes a unique project controlling has to be defined. This contains monetary methods like cost planning, revenue planning, budgeting and calculation as well as the planning of collaboration-wide processes. For a pre-evaluation of the processual and organizational behaviour of the collaboration we suggest a Petri net-based simulation (van der Aalst 1994). Herewith all process models and organizational models can be validated and verified. The simulation can also estimate lead-times, costs, and capacity utilizations and it can deliver useful data to optimize the processes and the organizational structure a priori.

An important organizational task of *Run-time-CMC* is the steering of the collaboration partners' behaviour. Used methods are e. g. collaboration-intern transfer prices or a repertory-grid-based soft-fact analysis to identify cultural weaknesses of individual enterprises concerning their cultural fit with the collaboration. Process oriented Run-time-CMC-tasks are e. g. integrated progress controls, which include process monitoring, capacity control or performance measurement.

Concerning CMC in general, the repository can consist of collaboration-internal data as well as external data. The CMC-results can on the one hand be used to optimize the collaborative processes. On the other hand the results are used as a knowledge-base for the modelling of succeeding collaborations.

4.6 Process Execution

The Virtual Service Platform is responsible for process execution and integrates operational applications of collaboration partners. It uses process data and organizational data from the repository. Workflow-functionalities (Hollingsworth 1995) realize process execution, while EAI-functionalities (Linthicum 2003) ensure data and process integration. By using *local adapters* (cf. Fig. 4), operational systems can interact with each other without implementing a central coordination instance. To perform the tasks of the adapter, used services are searched with a *location service*. When the *repository service* is triggered by an event from other adapters or by an event of an operational application, it reads the relevant process module and further belonging data like business- or output data. *Execution services* use the process definition to execute the process modules using the application services. *Integration services* convert different data formats. If necessary, the integration services have access to ontologies. When the process execution ends in the adapter, the next adapter is triggered to start the next process module. Therefore *interface services* arrange the interaction between the adapters.

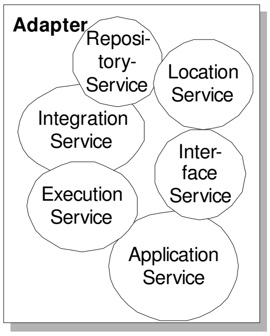

Figure 2. Components of Local Adapters

As a technical realization of the adapters, web service technologies are suitable (Werth et al. 2004). Services are available by using an extended version of Web Service Description Language (WSDL). So web services can interact with Simple Object Access Protocol (SOAP), based on internet protocols like Hypertext Transfer Protocol (HTTP) (Blake 2000). The Business Process Execution Language for Web Services (BPEL4WS or BPEL) allows the definition and execution of web service-based workflows (Shapiro 2002), while the Web Services Choreography Description Language (WS-CDL) defines the collaboration between web service components using a corresponding message exchange.

A further part used for the process execution is the *user interface*. A user in this case is a person or an organizational unit which fulfils functions and processes within the collaboration. Two different types of users can be distinguished. On the one hand they use presentation services as well as information services to get access to the repository (e. g. technical drawings, process definitions or visualizations of other data). On the other hand they use the "traditional" user interfaces of the operational systems in the companies to fulfill their tasks.

5 APPLYING THE ARCHITECTURE WITHIN AEC

5.1 Adapting the Architecture

The application of the architecture is exemplarily demonstrated in the context of tender, placing and accounting within a construction project.

Basically, the structure of the established architecture components as well as the technical realization can be adapted for AEC domain. Besides the necessary instantiation of tools, applications, and systems, the repository has to be enhanced.

The previously introduced data categories of the repository will be instantiated in regard to contents of the AEC domain, e. g. by using AEC-specific reference models. These have to be stored in AEC-specific data formats. Further information is needed to address special requirements of the output design for construction projects: *Reference and meta data* additionally contain feature data, output catalogs, and product catalogs addressing the specification of output data, while feature data are meta data for output and product catalogs. The output catalog specifies all possible outputs (material and non-material output) performed during all phases of a construction process within the AEC domain. The product catalog for AEC consists of reference product data describing product features independently from producers.

Within *primary data,* the output data becomes an instantiation with AEC-specific specifications and placing units. Specifications list concrete outputs (material and non-material output) of the current construction project. They are part of the construction contract and are used for tendering, placing and accounting of outputs for the construction project (GAEB - Gemeinsamer Ausschuss Elektronik im Bauwesen 2000). A placing unit represents an order which lists the output of a selected enterprise.

5.2 Phases of Output Description

At first, a plan designer uses software for *designing the collaborative output.* At this stage he refers to one or more output catalogs (*reference data*) of the *repository*. Result is a specification for the concrete construction project. This is stored in the *repository* using a standardized, AEC-specific interface. Afterwards, a bidder uses his calculation software *(operative software)* and reads the dedicated specification through the *Adapter*. Using the listings from the specification, the bidder uses product catalogs from the *repository* to determine calculation-relevant product data. A quotation is sent back to the planer, who negotiates the contracts and places the orders. Based on these results, a global-to-be-concept can be modeled and the resulting models as well as placing units are stored within the *repository*. The bidder imports his placing unit into his software and re-calculates it regarding the negotiation. Simultaneously, he procures necessary materials using an inquiry tool and/or procurement software. During the procurement, pricing changes are to be considered within the calculation software to create an exact calculation before the real construction process. These software tools can interact via the adapters as shown in chapter 4.

6 CONCLUSION AND FURTHER WORK

This article discussed an architecture for collaborations within AEC based on theoretical concepts of local and global knowledge in order to support all phases of the established collaborative business process management lifecycle. The architecture is an integrative concept which combines several existing approaches and presents a distributed repository as an integrative layer. Architecture's tasks are (1) to support modeling of business processes and collaboration structures, (2) to integrate these models into a common repository, (3) to enable a collaborative management & controlling based on these models, and (4) to use detailed models for automated process execution.

Because of the wide-spread requirements, the architecture becomes a large concept, so future work is modularized: One important question is the conversion of different business process and collaboration structure models into a unique repository format. Regarding this topic first work on a common repository has been done and is presented on DAIS 2005 in Athens, Greece (Theling et al. 2005).

Based on the repository, on the one hand models are used as input for simulation within CMC. Therefore a prototype for connecting simulation-tools to the repository will be developed. On the other hand reference models should be designed to facilitate the establishment of cooperation. Further on, the SOA paradigm should be taken into consideration. This leads to research questions concerning the implementation of adapters. For a proof-of-concept, showcases within the AEC domain are intended.

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