Transforming Inter-Organizational Business Processes into Service-Oriented Architectures

Method and Application in the Automotive Industry

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Abstract. Service-oriented architectures (SOA) promise flexible process integration in heterogeneous environments. Since services encapsulate application functionality according to business processes, the understanding of processes is a prerequisite for implementing an SOA. Existing SOA development approaches tend to focus on enterprise application integration scenarios rather than on business-to-business scenarios. Due to the increasing heterogeneity of applications in an inter-organizational context, significant benefits can be expected when implementing SOAs for business-to-business integration. However, a systematic approach to analyzing inter-organizational business processes and transforming them into SOAs is still missing. This paper presents a method for modeling inter-organizational processes and deriving business services in three steps. The applicability of this method is shown for a specific business-to-business scenario in the automotive industry.

1 Introduction

Business interoperability has become a key concern for enterprises establishing flexible and changing partnerships within their value chain. Being "interoperable" refers to the ability to integrate business processes with business partners, understand and process exchanged data, seamlessly integrate it into internal ICT systems and enable its beneficial use [9]. Recently, service-oriented architectures have emerged as an enhanced concept for integration in heterogeneous environments. In the context of B2B collaboration, an enterprise could simply expose application functionality as a service and thereby realize machine-to-machine process integration with its business partners. However, the business processes which companies execute at present are so dissimilar that no two companies could simply hook up their processes and underlying applications. A common understanding of the inter-organizational business process and the resulting process interfaces is a prerequisite for SOA-based B2B integration. A defined method is required to ensure an efficient implementation of SOA-based, inter-organizational process integration.

This method has to address the following questions (see Figure 1):

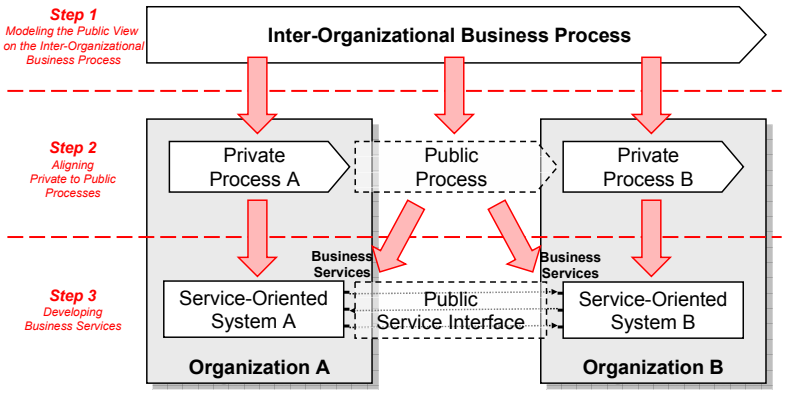

Figure 1 – Transforming Inter-Organizational Processes into Service-Oriented Architectures

- **Which artifacts have to be modeled in order to analyze and define inter-organizational business processes? What is an appropriate graphical notation for modeling the identified artifacts?** For this purpose it is necessary to analyze the characteristics of inter-organizational processes in comparison with internal processes. Having answered this question, model elements should be derived that are considered necessary for modeling inter-organizational business processes.
- **How can diverse private processes be aligned to one common public process? How can the challenge of discrepancies be met?** Private process design should be left to each partner as long as the result conforms to the interface that the public process specifies. In cases where private processes already exist, transformation and adaptation may become necessary to comply with the public process.
- **How can specified model artifacts be mapped onto constructs of an SOA-based integration architecture executing inter-organizational business processes?** The means employed must make it possible to map model artifacts onto corresponding components of SOA-based integration architecture. The interfaces of the public process should be implemented as business services. Workflows have to be defined from the aligned private processes and connected to public business services.

To answer these questions a method will be introduced containing a coherent approach to transforming models of inter-organizational business processes into components of an SOA-based integration architecture. This method has been applied and validated by a consortium of automotive manufacturers and suppliers who are currently redesigning their inter-organizational Engineering Change Management (ECM) processes. With suppliers taking over responsibility for the development of entire components or modules, the identification, evaluation and implementation of engineering changes in series production requires a joint effort of both manufacturers and suppliers. The recent VDA recommendation 4965 [17] defines a reference ECM process which has formed the starting point for the SOA design in this specific case.

The following section provides an overview of the background and related work (Section 2). A framework of conceptual inter-organizational business modeling is

then defined containing a public process model which serves as reference for the participating organizations (Section 3). Once the public process has been derived, the existing private processes have to be assigned and eventually aligned to the agreed public process model (Section 4). The results of these efforts establish the basis for transforming the public artifacts into SOA components. The public process interface is realized by business services leveraging web service technology (section 5). The business process model is used to derive XML-based business documents that are exchanged between business services. In addition, private process modules are transformed into workflows for business process automation which later can be implemented using the Business Process Execution Language (BPEL).

2 Background and Related Work

There are several methods and modeling approaches to developing IT solutions to support business processes. Examples are the Business Engineering approach [14], the ARIS method [7] and the Model-Driven Architecture (MDA) approach [12]. Business Engineering suggests a systematic, engineering-oriented approach to map the company strategy onto business process and application architecture. The ARIS method provides an integrated modeling approach for an enterprise architecture and comprises Event-driven Process Chains (EPCs) as process modeling notation. MDA defines three modeling layers, which enables a model-driven development of software. The existing methods derive information system design from business level models, but so far do not consider inter-organizational business processes.

Inter-organizational business processes are performed by multiple independent parties. Since organizational borders usually represent boundaries for system interactions and data flow [1], a number of particularities arise in comparison with company-internal business processes. Inter-organizational business processes usually do not have a centralized control instance or process owner. Coordination between the different organizations requires an agreement on how to interact and exchange information [3]. However, autonomy of the different parties has to be taken into account when designning inter-organizational processes. On the one hand, an organization should be able to flexibly participate in interactions with different partners with minimum impact on the internal processes. On the other hand, an organization must be able to conduct internal process changes without changing existing collaborative scenarios [16]. Within individual organizations different terminologies are used and multiple standards for data sets inhibit a seamless integration of inter-organizational processes [5]. A partner must be able to provide internal information on private data and processes at different levels of abstraction depending on the intensity of business collaboration [3].

Important contributions to handling the particularities of inter-organizational business processes come from research on workflow management, e.g. Collaborative Process Management [11], the Public-To-Private Approach [4] and the Process-View Model [16]. They distinguish between internal activities (private process) and the inter-organizational interaction (public process). At the same time, they introduce abstraction concepts which allow details of the internal business process to be hidden from external partners. The public process concept is also used by B2B standards like RosettaNet [15] which defines Partner Interface Processes (PIPs). However, B2B

standards do not usually take into account how private processes are to be connected to public processes.

Business partners should be able to capture the requirements of inter-organizational business processes through high-level, graphical languages which are focused on the business level. Current business process modeling notations do not consistently support inter-organizational model requirements and concepts [1, p. 18]. This applies to the Unified Modeling Language (UML) which has a strong background in software engineering. In contrast to UML, the Business Process Modeling Language (BPMN) [13] provides the necessary model elements to define inter-organizational process models. However, BPMN has not become widely established in the industry so far. In practice, and particularly in the automotive industry, process models are defined with event-driven process chains [7]. This notation has recently been extended by [8] to cover inter-organizational processes. However, EPCs do not yet adequately consider the transformation of processes into SOAs. Nevertheless, because of the dissemination of EPCs in the industry, the method presented in this paper extends EPCs to model inter-organizational business processes and to transform the identified artifacts into SOA components.

3 Step 1: Modeling Inter-Organizational Processes (Public View)

Once requirements for modeling inter-organizational business processes have been identified, model elements and their graphical notation have to be derived (Figure 2).

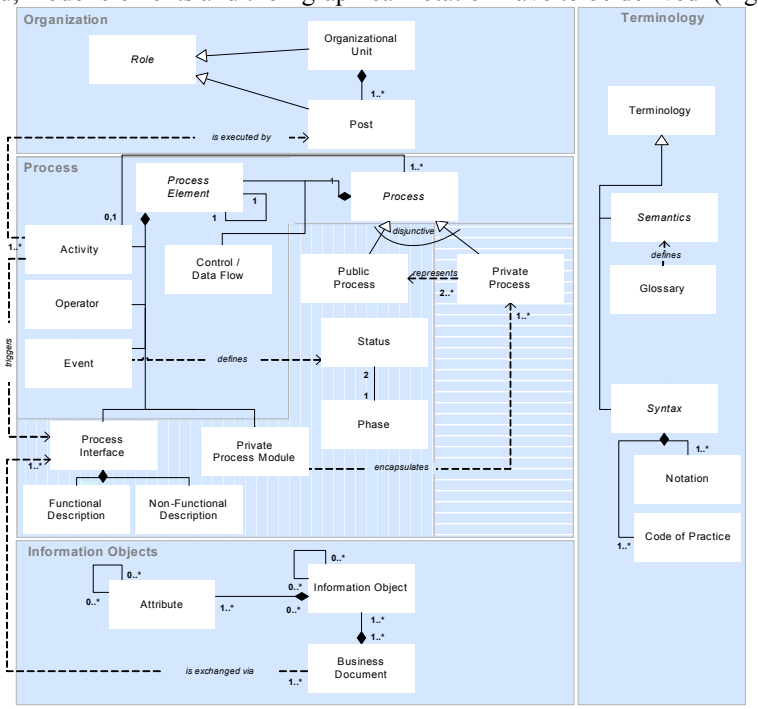

Figure 2 – Meta Model for Modeling Inter-Organizational Business Processes

These elements can be structured in different model categories which together provide a framework for modeling inter-organizational processes. Three model categories are regarded as necessary for defining the inter-organizational interaction:

- The *role model* provides an overview of the different roles involved in the cooperation on the organizational and position level.
- The *process model* describes the activity flow performed by the different roles and details the process interfaces between organizations.
- Finally, the *information model* represents the relevant information objects and serves as a basis for defining the message content.

The role model describes the responsibilities of persons and organizational units that are directly involved and visible to external partners. Thus, it establishes a common understanding about how the cooperating partners interact. This is regarded as a prerequisite for modeling the inter-organizational processes. The major artifacts are roles and organizational units or positions. A role description defines responsibilities and functions. Roles may be assigned to the level of an organizational unit or a single person who executes an activity. Organizations and persons may perform multiple roles.

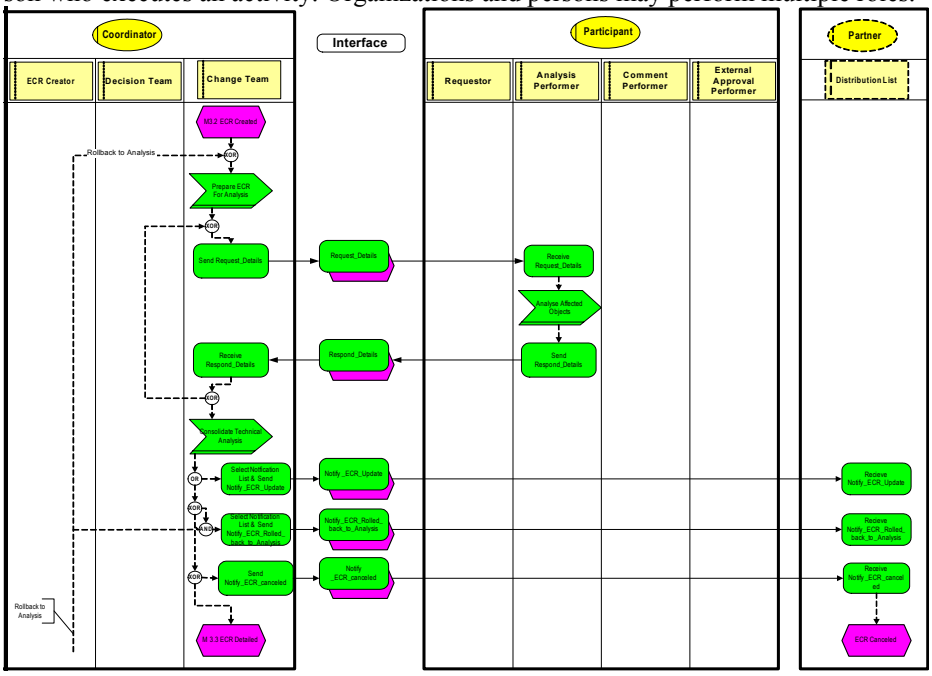

Figure 3 – Public Process Model
(Example: Phase "Technical Analysis of Engineering Change Request")

The public process model is the most important element of the framework for modeling inter-organizational processes. It defines the sequence of activities which are performed by the different roles: The model focuses on the public process which contains the main activities which business partners have to agree on in order to perform an inter-organizational cooperation. The public process is a view of the entire inter-organizational processes. It uses the abstraction concept and conceals details in the private processes of the individual partners behind a special arrow symbol (see Figure

3). In this example, business partners only have to agree that the affected objects are analyzed which results in so-called details to the engineering change request (ECR), but they do not need to define exactly how this analysis is performed.

The process interface between cooperating partners needs to be further detailed in order to provide the input necessary for service design and enable the transformation of model artifacts into SOA-based integration architecture. In doing so, messages can be added containing the information objects that have to be exchanged. Also, quality of service parameters, conditions and restrictions can be specified, for example error rate, duration of response, flexibility, costs, etc. which may be the basis for contractual agreements between business partners.

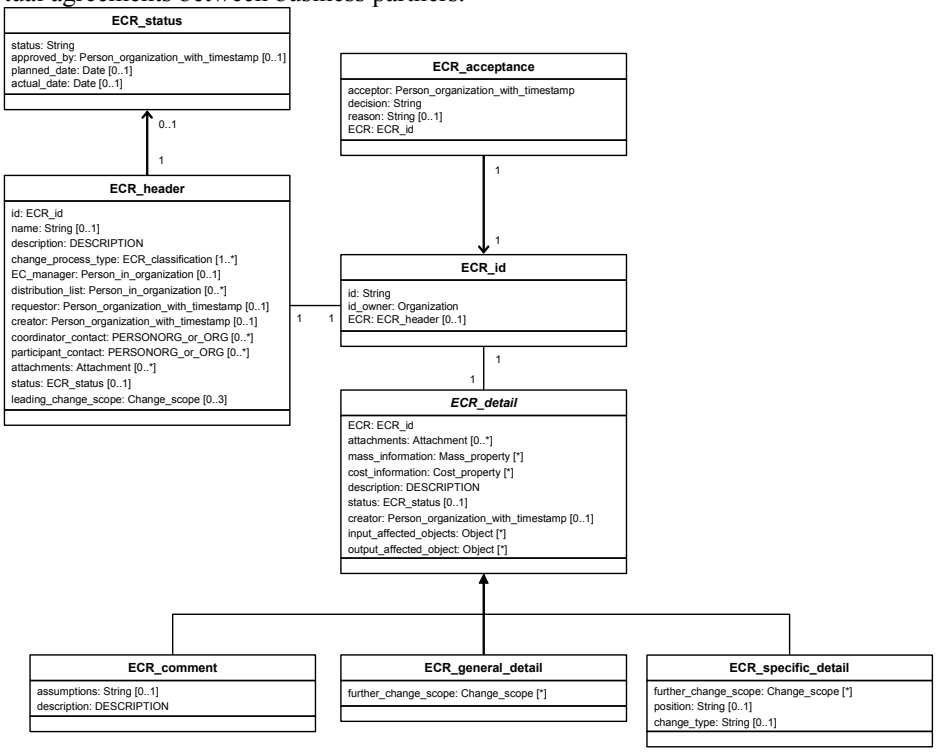

Figure 4 – Information Object Model of an Engineering Change Request (Extract)

To this purpose, the information object model establishes a terminology of reference among the cooperating partners and aligns the different semantics. The information model structures the necessary information objects which have to be processed along an inter-organizational process. Simplified UML class diagrams are used to define the objects and their relationships. Each class represents an information object which is further described by attributes. Figure 4 outlines the relevant information objects for describing an engineering change request in the automotive industry. As an example, it comprises the basic description of an ECR (in the ECR_header class), classification and status information (e.g. ECR_status,

ECR_acceptance) as well as further analyses which are performed during the processing of an engineering change request.

Messages / Information Objects	ECR_id	ECR_header	ECR_status	ECR_general_detail	ECR_specific_detail	ECR_comments	ECR_acceptance
Request_details	m	o	e	M	o	o	na
Respond_details	m	o	e	m	o	o	na
Notify_ECR_rolled_back_to_analysis	m	o	m	o	o	e	m
Notify_ECR_cancelled	m	o	m	o	o	o	m
Notify_ECR_updated	m	m	m	o	o	o	o

Figure 5 – Messages and their Composition Based on Information Objects (Example)

The information model is extended by the definition of the single messages. The relation between messages and information objects is defined in a table (see Figure 5). The following relation types can be distinguished: (m) mandatory, (o) optional, (e) extension, and (na) not applicable. For example, the message “Request_details” must contain an “ECR_id” and an “ECR_general_detail” object. It may contain an “ECR_header”, an “ECR_specific_detail” and an “ECR_comment” object. The “ECR_status” object has to be defined individually. The “ECR_acceptance” object is not applicable. In our example, the messages combine different information objects as reusable modules.

In summary, public process, information and role model ensure interoperability on a process level.

4 Step 2 – Aligning Private to Public Processes

The main result of the first method step is a well-defined public process model which defines roles, the main information objects, the sequence of activities and process interfaces, including specified messages. Each partner has to be able to comply to that public process model in order to ensure business interoperability with other partners. As a consequence, private processes of each individual partner have to be systematically assigned and eventually aligned to the committed public process in a next step. This implies mapping artifacts of the defined public process onto the artifacts of the individual partners in terms of the role, process and information object model. The following steps are performed:

1. Alignment of *organizational artifacts*:
   Roles which are defined internally by the individual partners have to be assigned to the roles defined in the public process model. The cooperating partner has to be able to perform the functions and take over responsibilities as defined in the role model. For example, the reference ECR role "Requester" has to be mapped onto the internal role performed by an individual employee, who typically starts the engineering change request and could be named "Initiator", for instance.
2. Alignment of *informational artifacts*:
   Information objects of the public process model must be mapped onto internal information objects. For instance, the specified attributes for "ECR_Header" have to be mapped onto the attributes which are used for the basic description of an ECR in the partner's information model.
3. Alignment of *process artifacts*:
   Since individual organizations typically are very reluctant to changing their business processes, the alignment is not performed at the activity level, but focuses on the synchronization points in the inter-organizational interaction. The objective of this step is to synchronize the main phases and milestones of the public process model with the partner's private processes. For example, the reference phase "Technical Analysis of ECR" can be mapped onto the partner's phase "Change Evaluation" provided that both phases result in a detailed ECR.

To cope with the challenge of discrepancies in the alignment of private processes, different cases and arrangements have to be considered. In the context of the application in the automotive industry, some heuristics for dealing with informational, process-related and organizational discrepancies have been suggested:

- There are more phases or states defined by the reference process than by internal processes: If the defined phases or states are necessary for the interaction of business partners, these also have to be defined as part of the internal processes.
- There are fewer phases or states defined by the reference process than by internal processes: Additional internal phases or states are irrelevant for the public process since they are encapsulated.
- Internal phases or states mutually overlap with phases or states of the referenced public process: The internal phases or states have to be aligned to defined phases or states of the public process.

The alignment of private to public elements is a prerequisite for successful inter-organizational process coordination. As a consequence, models of private elements have to be mapped onto public processes model and vice versa. Apparently, this mapping is not trivial and cannot be processed automatically. Particularly in the case of structural discrepancies, a redesign of private elements may be required in order to comply with the inter-organizational process model.

5 Step 3 – Developing Business Services

To support inter-organizational processes by means of an SOA-based integration platform, public business services have to be derived from the public process interface, as mentioned above. In order to develop the SOA-based integration platform, the Model-Driven Architecture (MDA) approach is applied. The private and public

process model defined in the previous sections can be seen as a Computational Independent Model (CIM) and serves as an input for developing a Platform-Independent Model (PIM).

Figure 6 gives an overview of the MDA-compliant transformation from Computer-Independent Models (CIMs) into Platform-Independent Models (PIMs). Model artifacts from the CIM level are transformed into components of an SOA at the PIM level. Internal private processes are thus transformed into automated workflows with user interaction by desktop integration mechanisms such as portals. Workflows orchestrate services that encapsulate functionality of existing applications.

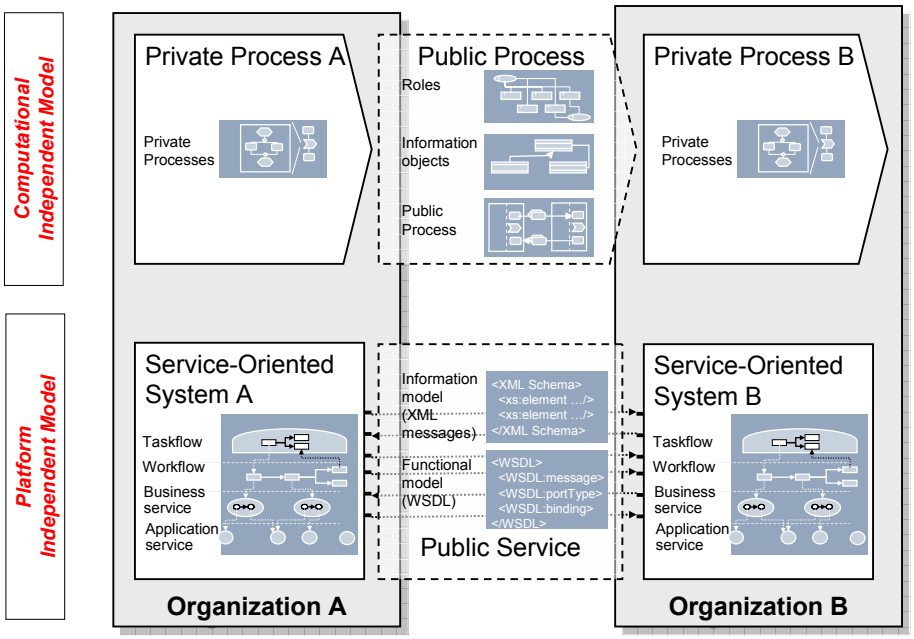

Figure 6 – MDA Approach for Developing Business Services

The public process interface artifact is of special interest as it links the different organizations. Since we assume that business processes are executed by the individual business partners without central coordination, the internal workflows are triggered by public service calls. The design of the business service for the Engineering Change Management scenarios is discussed at length in [10]. A business service of this kind is developed by following a two-step approach:

- *Informational service design*: According to the message definition in step 1, business documents have to be specified and implemented. For message implementation, XML schema representation has been chosen and design rules for XML business documents are applied (OAGIS 9.0). To allow flexibility in respect of further changes, a modular specification of XML schemas is suggested: Basic data type XML schemas contain the definition of ECR data types. This is complemented by a minimal message XML schema that contains information objects used in all messages. On top of these two generic message

XML schemas for each specific message, an own XML schema is constructed containing message-specific information objects. The advantage of the modular XML schema structure is that changes are locally limited and reuse is enforced.

- *Functional service design*: When designing the service interface, the granularity of a service has to be defined. Criteria for the decision of granularity are, for example, cohesion of specified operations and loose coupling [10]. A functional description of the business service contains the signature of operations invoked by business partners. This includes input and output messages. In the automotive project it was decided to develop only one service to provide ECR business interoperability and to represent every public process interface by a dedicated service operation. Figure 7 depicts the resulting functional model of the ECR Business Service. This approach represents a business-oriented service design as opposed to design options which target at providing very generic interfaces.

In a next step, this service interface description can be transformed into the platform-specific model (PSM) of each business partner which reflects the individual integration and application architecture.,In our example from the automotive industry, the ECR Business service is now being implemented by several automotive companies based on different integration platforms (e.g. SAP XI, IBM WebSphere, Inubit) and engineering change management systems (e.g. SAP PLM, Axalant, Lotus Notes).

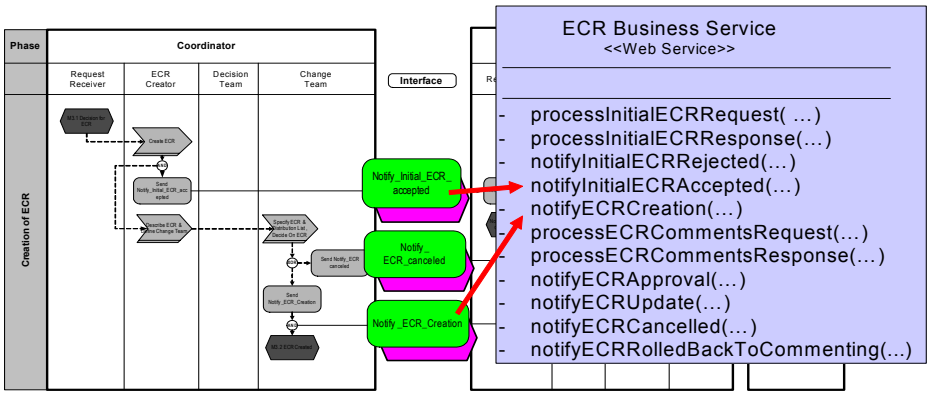

Figure 7 – Transformation of Public Process Interface to Service Operations

6 Conclusion and Outlook

This paper presented a method for mapping inter-organizational processes onto service-oriented architectures. The modeling of inter-organizational business processes provides the conceptual input into the design of B2B services and thus represents the computational independent model. It consists of a role model describing the responsibilities of the cooperating partners, information objects which have to be exchanged via messages and process model elements defining the public cooperation process. For the representation of these model elements the EPC approach was extended. The integrated modeling framework is the starting point for aligning

private processes of cooperating partners to the common public process model and transforming model artifacts into components of an SOA-based integration platform.

As proof of concept, the method has been successfully applied in the "SOA for Automotive" project in which OEMs and suppliers are redefining their interaction in the Engineering Change Management process. As an example, a part of the ECR process was detailed and mapped onto SOA components. Several workshops were therefore held to analyze private processes of partners, to align private processes to the public process model and to derive the service design. The experience gained from the project has revealed that necessary prerequisites for mapping inter-organizational processes onto an SOA-based integration platform are consensus and commitment to the public processes as well as a close alignment of the service implementation.

As further work, the transformation of CIM artifacts into components of the SOA will be extended and automated. The transformation of process models into the Business Process Execution Language is the key concern here. Moreover, the specification of qualitative aspects - for example according to the business service - is of special interest. These QoS specifications should be mapped onto management solutions that allow the qualitative behavior of services to be monitored.

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