A Case Study in Enterprise Modelling for Interoperable Cross-Enterprise Data Exchange

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Abstract: In this paper, we describe an approach to validate the capability of the ATHENA-enhanced enterprise modelling solutions to capture necessary cross-organizational business information in a computable form and to exchange partial models using a proposed common meta-model. The basis for the validation is the Electronic Kanban replenishment process and data interchange protocol that has been standardized to support the Inventory Visibility and Interoperability (IV&I) project for the automotive supply chain. The paper discusses results of and lessons learned from the validation process.

Keywords: enterprise modelling, interoperability, business applications, business process

1 Introduction

The key idea behind enterprise modelling (EM) for interoperable cross-enterprise data exchange is to achieve interoperable applications at the business process level across multiple enterprises**.** Currently, there exist many languages, methodologies, and tools in support of EM. The EM languages provide constructs to model roles, operational processes, and functional contents, as well as support information, production, and management technologies. However, integration of the models generated with different EM tools and their languages used by different enterprises cannot be done easily today [1-3].

In the Advanced Technologies for Interoperability of Heterogeneous Networks and their Applications Integrated Project (ATHENA IP), the Process, Organization, Product and others (POP*) meta-model and Modelling Platform for Collaborative

Enterprises (MPCE) for supporting interoperable cross-enterprise data exchange approaches are developed [1, 5, 6].

The following case study presents an approach to validate (1) the capability of the ATHENA-enhanced EM tools to capture necessary cross-enterprise business process information in a computable form and (2) to perform interoperable cross-enterprise data exchange founded on POP*-based translation of partial models and using two different enterprise modelling representations.

The electronic Kanban (eKanban) replenishment process and data interchange protocol, standardized by the Automotive Industry Action Group (AIAG) as a part of the Inventory Visibility and Interoperability (IV&I) project is a basis for the validation [7]. The goals of the IV&I effort were to identify and drive the adoption of a common, electronic signalling process for the Kanban protocol for both large and small trading partners in the automotive industry supply chain.

In this context, Section 2 gives a brief background about the EM methodology while Section 3 explains the details of the general validation approach. Section 4 elaborates on the results achieved. In Section 5 we account for the lessons learned and in Section 6 we discuss the future work.

2 Background

We provide a short description of the Integrated Enterprise Methodology (IEM) that is a holistic, methodical basis for business process modelling used in our validation effort [8].

2.1 Modelling formalism

According to the IEM methodology, the core of the model structure contains the information view and the process view. The information view includes the class structure, the part-of relations and the class attribute definitions. The process view shows the main functions of the enterprise system and flows of information or materials between these functions. The IEM methodology is based on three generic object classes: *Product*, *Order*, and *Resource*. The *Product* class describes objects sold by the enterprise and the product components that may be included in a final product. The *Order* class information is used to plan and control processes or activities in the enterprise (e.g., customer, design, and production orders). *Resources* are the service enablers within the enterprise such as the equipment and human resources. The required enterprise data and business processes (i.e., the tasks referring to the modelled objects) are structured in accordance with the generic object classes and their subclasses. The basic principle in the process modelling is hierarchical structuring of the business process model. The IEM methodology is supported by the MO²GO tool [11].

2.2 ATHENA-based enterprise models mapping mechanism (POP*)

The POP* meta-model was developed to support model data exchange between different enterprise modelling tools that reflect either complete or partial enterprise architectures. The approach is greatly inspired by already existing initiatives and standards, of which the process oriented BPDM, UEML1.0 and ISO/DIS19440 are prominent [5][4]. Although some overlap in motivation and scope may be found between POP* and these initiatives, the ambition of ATHENA is for POP* to take a holistic approach, covering all relevant aspects of collaborating enterprises. So far, the strongest focus has been on covering the Process domain. This domain is recognized as the most complex but also the most fundamental to the enterprise modelling. However, the Organization, Decision, Product, and Infrastructure dimensions are also addressed by introducing relevant concepts and relationships. Hence, by serving as a model exchange or model mapping device, POP* aims to facilitate interoperability between collaborating enterprises using different modelling languages.

A repository based on the POP* specification stores models represented using different modelling languages and tools. The various tools supported include: METIS –Troux Technologies, ARIS – IDS Scheer, MO²GO – IPK Berlin, GRAI – ADELIOR and UML-Rational Rose [14]. Every tool can only change modelling elements in the repository, that are mapped to the own modelling language. The advantage of this approach is that model parts based on concepts that are not integrated in one tool will not be deleted during the transformation.

3.1 Problem statement and expectations

Currently, the AIAG business process modelling based on capturing interoperability requirements at the highest level of the overall enterprise, uses a manual process. In this traditional process, a methodology (i.e., the Unified Modelling Methodology (UMM) from UN/CEFACT) is a basis for capturing and documenting the business level and enterprise requirements within a pre-designed collection of textual forms [3][7]. These requirements naturally follow from the desired physical and virtual interactions of the actors that, based on their corresponding roles, enable the desired business process.

By using the ATHENA-based EM tools in these early stages of requirements identification, gathering, and analysis; our goals are to achieve the following:

- Computational representation of a well-defined business process model within the overall cross-organizational eKanban enterprise model. Today, the enterprise-level requirements are captured in a textual format based on use cases and activity flow diagrams, which cannot be consumed systematically. With a computational representation, a greater precision of describing these requirements as well as inclusion and consideration of a greater number of requirements in a holistic enterprise framework is expected.
- Well-defined data interchange requirements. Today, the data interchange requirements that are captured at the business process modelling level are documented as free text within the process deliverables. However, with the computational model at hand, it is expected that these data interchange requirements will be discovered as a by-product of the business process modelling activity within the specific context of business transactions [12].

- Shareable business process model. We expect that the computational representation of the business process model may be shared by a range of EM tools.

The main idea behind the POP* methodology is to provide a common format along with a mapping methodology by which mappings from the various EM languages (EMLs) to the common format can be defined so that models represented using different EMLs may be exchanged. For this idea to be successfull, the following needs to hold:

- The POP* meta-model must contain concepts and relations, that are sufficiently generic, making it possible to define sensible mappings from any major EML.
- The POP* meta-model must not be overly generic nor too large, as this will inevitably cause loss of semantics during model conversion to POP*.

We consider the above challenges to be a good start for our validation goal of POP*. In the next period we will try out POP* in a real, IV&I eKanban case. We expect that our experience will help to improve and further develop the POP* methodology.

3.2 Validation Process

The overall validation goals are the following:

- Validate IV&I eKanban specification improvement.
- Validate ATHENA-based enterprise model mapping mechanism (POP*).

The following are the phases of the adopted validation approach, as proposed by the Fraunhofer Institute for Production Systems & Design Technology in Berlin (IPK): (1) Modelling, (2) Process Assistant (PA) implementation, (3) PA Validation (based on a validating interview with business analyst), (4) the Model Exchange and (5) Analysis of the Model and Exchange Results [8] . The phases 1-3 correspond to the first validation goal, while phases 4 and 5 are related to the second. Key steps within the above phases are explained next.

During the **Modelling phase**, in the first step, the initial eKanban business process model is developed on the basis of the eKanban specification document. This step is important to get a common understanding of the terminology used within the eKanban specific domain and to have a mapping between the application domain and methodology. In the next step, the additional modelling activity refines the eKanban business process model to the level of the atomic concepts. As a result of this step, the IV&I Reference Model is developed.

In the **PA Implementation phase**, on the basis of the model specification, PA is generated automatically by the MO²GO tool. Different methods of knowledge mapping can be employed to visualize the developed knowledge structure. The PA is an application that represents knowledge and information according to organizational business processes, organizations, and systems as html text with links to a graphical viewer. The MO²GO Viewer and PA may run within Web browsers.

Finally, in the **PA Validation phase,** the PA views, that are created in the previous phase, are presented to the business analysts. The basic purpose of the PA, as well as the advantages of this kind of business analysis, will be introduced to them. The basic focus of the analysis will be on the eKanban data exchange requirements.

In the **Model Exchange phase**, three essential activities are of interest. The first one, which is the most important task, is to define a mapping that establishes relationships among POP* constructs and elements of EMLs that should be translated. This step is needed only if one of the EMLs has never been mapped to POP*. The second task, always based on the previously defined relationships, is to translate native models expresed in different EMLs into POP*. Transforming a native model to POP* does not imply only the translation of the elements one by one. For that purpose, we defined specific rules how POP* elements can be associated in the IV&I eKanban case. Finally, we must generate an XML file for model interchange, using the XML Interchange Format (XMI) for POP*[5]. XMI file will be automaticaly generated by the MOGO tool and imported into ARIS tool [1].

The last phase we perform is a **validation analysis of the model and the exchange**. Possible measures of validation are (1) portion/percentage of the original business process model captured and the model quality and (2) portion/percentage of the data exchange requirements captured and exchanged.

4 Project results

Currently, the validation project results include the IV&I eKanban EM, the IV&I Reference Model, and the PA application.

4.1 IV&I eKanban EM

4.1.1 Identification and classification of the relevant objects

The main focus of the IV&I eKanban project is communication between Customer and Supplier that is supported by IT systems with visualization capability for the purpose of transmitting order requirements and fulfillment response by the Supplier. The information flow is based on the order elements. Therefore, the orders are modelled in more detail than product elements. The only product for a specific eKanban business process is the Kanban container that represents one standard pack with a unique Kanban serial number.

The *Order* class, however, was an interesting special case. In order to identify all necessary IT requirements, we had to introduce two communication elements, *Signal* and *Event*, as subclasses of the *Order* class and to emphasize their differences. Both *Event* and *Signal* are manifestations of a change in a system state indicating that something significant has happened. The main difference is that the *Signal* is generated by the Visibility tool or an IT-system while the *Event* is related to the physical world.

With resources, the main focus is on organization units and necessary documents for execution of the eKanban process because the actors need to define and to accept business conditions before the beginning of any cooperation. The main actors in the system, Supplier and Customer, are subclasses of the *Organization unit* subclass. All required documents are represented as instances of *Documentation* subclass and linked to the eKanban model.

Two basic types of documents are identified for the AIAG eKanban specification: *eKanban Specification Document* and *eKanban Operational document*. *EKanban Specification document* subclass is needed for defining general rules and conditions of the business. This subclass is further decomposed into *Full document* and *Partial document* subclasses. The *Full Document* subclass represents documents that are more general and connected with the whole business process. *Partial Document* subclass defines conditions that are typical for given processes at the lower hierarchical levels of decomposition. A *Full Document* instance may consist of one or more *Partial document* instances. To facilitate comprehension of the eKanban model, a reflection is enforced between the class structure and the business process hierarchy. For instance, *Rules and procedures for eKanban* is an instance of the *Full Document* that, at the highest level of the model, represents all rules and procedures collectively. *Partial documents* are assigned directly to the activities at the lower hierarchical levels.

Operational document type is intended to support daily business and collaboration between Customer and Supplier. For example, when the shipment is prepared to leave the dock, the *Advanced Shipment Notice (ASN)* is sent to the Customer, who in turn sends a copy to the carrier's system. With the sending of the ASN, a multi-part form is often printed to go with the shipment and serves as a carrier bill-of-lading. In the model, ASN document is assigned as a resource to the *Move shipment* activity. The structure of *Resource* subclass is displayed as a structogram, in Fig.2.

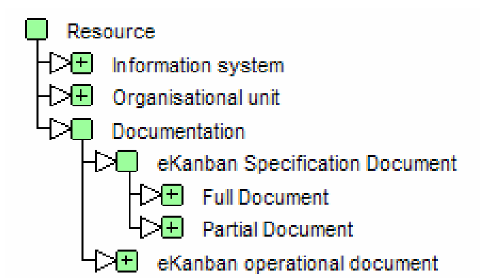

Fig.2. High levels of the reference class structure for resources

4.1.2 Modelling of the processes

At the process modelling time, we were concerned with the different functions and their logical processes, the actors involved in the function execution, the data documents, the information systems, and the existing data flows that are regarded as necessary. The use cases in the eKanban specification document are well-structured.

For each use case, the actors with their possible roles and the steps for use case realization are provided. According to the use case definition and principle of hierarchical decomposition, the total business process is captured at the highest level of the model, and contains two activities that are shown in the Fig.3: (1) *Run eKanban* and (2) *Establish cooperation by setting up documents*. The *Run eKanban* activity is an abstraction of the eKanban execution. At the top model level, all operational processes are present together in the form of *Run eKanban* activity. *Establish cooperation by setting up documents* presents an integration of planning and establishing processes that provide needed resources for executing *Run eKanban* activity and related operational processes.

Each use case from the specification document is present as an activity at the first level of decomposition. For example, the Kanban authorization use case is present as *Authorize Kanban container* activity, with the following steps of the use case execution: (1) *Evaluate authorization*, (2) *Publish signa,l* and (3) *Receive authorization*. They are present as activities at the next hierarchical level.

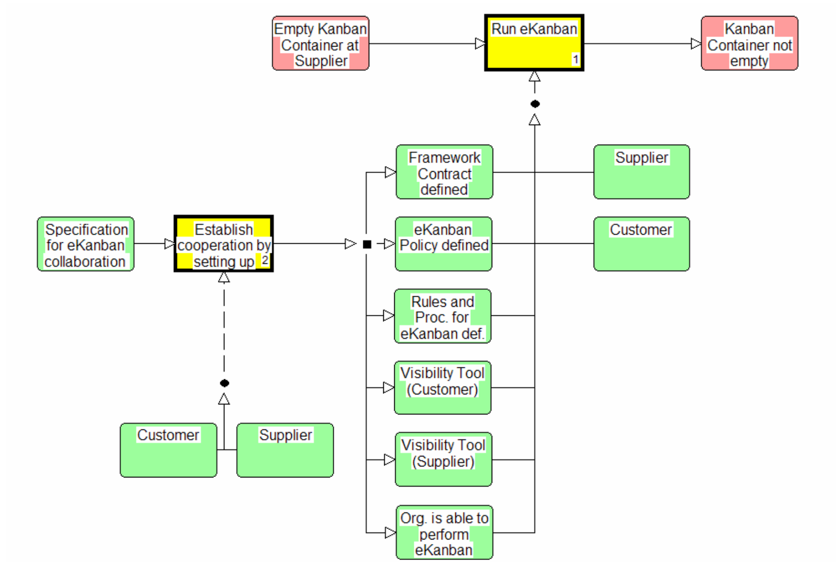

Fig.3. IV&I eKanban EM – top level

The first level of decomposition of the *Establish cooperation by setting up documents activity* contains two flows: *Project management* and *Project execution*. The *Project management* flow contains necessary activities to define project objectives and to perform project planning and controlling. The *Project execution* flow includes establishing the process with necessary assessment procedures to identify the current maturity for collaboration capabilities according to the Enterprise Interoperability Maturity Model (EIMM) [16]. This assessment and the methodology to derive the right project and modelling approach ensure an adequate implementation regarding the objectives and the current capabilities of the participating enterprises. All rules, procedures and polices, that are inevitable for operational processes, are defined with the help of the activities of the Project execution flow. This means the object and message definitions elaborated in the establishment process are reflected completely in the operational processes. This approach to integration of operational with enabling processes is important to elaborate the requirements for IT Infrastructure and for following a structured approach consistently.

At the first level of decomposition of the *Run eKanban* there are two flows: *Control flow* and *Material flow*. The *Material flow* captures the movement of the physical Kanban containers. The *Control flow* manages the dynamics of the business process using the *Order* class elements.

4.2 IV&I Reference Model

This section provides an overview of the IV&I Reference Model architecture. First, a general overview of the basic components is provided and the underlying structure is discussed. Second, the pattern defined for eKanban execution is described. Finally, some remarks are made about the partial model significance.

IV&I Reference Model includes class structures, template models, and a manual that describes the correct and efficient use of the model. The key benefit that IV&I Reference Model brings to the eKanban engineering is that it enables a focus on a standard way of requirements representation. The IV&I Reference Model incorporates additional elements like standard description of processes, standard metrics, and best-in-class practices. Its purpose is to provide a foundation for systematic development of the AIAG eKanban business process by providing a common frame of reference for different modelling entities at the same abstraction level. Thus, IV&I Reference Model can be seen as a common language that can be used to translate basic expressions from the eKanban specification to the IEM Reference Model standard form that we adapted for specific eKanban specification needs. For instance, the reference class structures define common terms for objects and enable overall evaluation procedure of the model. Furthermore, these classes inherit specific attributes that enable discussion and comparison of the shared total or partial models between distributed teams (e.g., for each class we defined a special attribute *Description,* that explains its purpose in the whole eKanban business process). The high-level class structures for resources are illustrated in Fig. 3. Separate exports for each class are generated automatically, and can be exchanged easily between the Customer's and Supplier's IT-Systems.

For handling similar modelling problems between the Customer and Supplier, a collection of modelling patterns was created. For example, with the help of the *Exception handling* pattern, all exceptions in the model may be handled. (We provide an account of our experiences with application of patterns in the section *Lessons learned*.)

The IV&I Reference Model includes partial models that are combined logically for a generic example of running IV&I. The partial models are expressed as models that capture relevant information for main communication events, which are identified on the basis of the eKanban specification. For example: partial model *Communicate consumed Kanban* is relevant for the use case that is executing when the Customer notifies the Supplier that a Kanban container was consumed.

4.3 Process assistant (PA)

In order to make the captured knowledge structure relevant to the daily collaboration activities between the Customer and Supplier, it is necessary to take the process context into consideration. We find the PA application suitable for this task.

In the PA, according to the roles and competencies in the eKanban business process, different views are created. By deriving general as well as eKanban-specific views, the end users are able to navigate the model without the need for a specialized modelling knowledge. The *Processes*, *Organization structure*, *It-Systems,* and *Glossary* views are typical to all PA applications. For example, each activity in the model is represented in the *Process* view. This view also includes links to all relevant sub processes, shared organizational units and responsibilities, pre-conditions, post conditions, and exceptions to the process execution. The *Organization structure* view provides the description of the organizational structure, the responsibilities of the individuals, and the organisational units within the eKanban business process. Main links in this view are *Supplier*, *Carrier*, and *Customer* with the list of processes in which they participate. *It-Systems* view contains information about necessary IT requirements for process execution. *Event and status of eKanban* view that represents a list of all communication events is implemented specially for eKanban to provide integral information about the process that generates event, the process which receives it, and the status of Kanban container after communication. For example, after the *Communicate consumed Kanban container* event, status of the Kanban is set to empty. *Documentation* view is adapted for the analysis and improvement of planning and establishing the entire eKanban cooperation. For instance, the real documents, like ASN, are linked as document files.

5 Lessons learned

Overall, we were pleased how the IEM methodology and MO²GO tool supported the modelling of the eKanban business process leading to a transformation of the eKanban business process specification into a consistent enterprise model.

We discovered it was important to adapt the general IEM method by further revising and extending the methodology concepts in support of the eKanban modelling procedure. We were able to introduce specific rules and constraints for the eKanban model by using attributes in the class structure. For instance, a semantic disambiguation was important to emphasize the difference between concepts like *Signal* and *Event.* A *Documentation* attribute of the *Signal* subclass states precisely that a signal is generated by an Inventory Visibility tool. That information was essential to account for the necessary IT requirements.

Using the MO²GO tool, it was possible to define eKanban-specific products, orders, and resources for their use during the business process modelling. For example, we introduced *Documentation* subclass and the MO²GO tool was used to define specific relations among the identified documents. Besides the standard hierarchy, additional groups of documents needed to be created with the *List of components* element. A typical example was *Rules and procedure for eKanban* subclass that represents a combination of *Full documents* and *Partial documents* subclasses. Documentation about components of the eKanban model was generated automatically by the tool. This gave us insight into all derived classes and their relevant features and we were able to react and adapt to changes in a flexible manner.

We were able to complete all the planned steps, per the IEM methodology, with only two significant issues: pre-conditions specification and exception handling. According to the methodology, pre-conditions to a process could be present within the model in the form of attributes or a sequence of functions. Pre-conditions in a specific eKanban use case are stated mostly in the form of documents. For example, necessary pre-conditions for execution of the *Kanban authorization* use case are defined rules and procedures for Kanban authorization. In the manual eKanban system they are represented in the form of physical documents. We came to the conclusion that documents should be introduced in the model as necessary resources for an activity execution. Consequently, besides the *Material* and *Control* flows, an additional resource flow is introduced: the *Project execution* flow, that defines all necessary activities for documents definitions. The *Specification for eKanban realization* resource element initiates the *Resource* flow. Ending states include: (1) *Framework contract defined*, (2) *eKanban policy defined* and (3) *Rules and procedure for eKanban defined:* These states are assigned as necessary resources to the *Run eKanban* activity at the top model level (shown in Fig. 3).

Although the exceptions were left out of scope from the first version of the eKanban business process specification document, they were included in the eKanban model to establish common understanding of the total process. By creating *Exception handling* subclass and organizing exceptions into a series of hierarchical groups, we managed these classes to support the eKanban exception handling. We found it useful to define a pattern in support of exception handling management. The defined pattern is a part of the IV&I Reference Model and is applied to all identified exceptions in the eKanban process.

Besides patterns, partial models also proved to be an important part of the IV&I Reference Model because distributed modelling of one model is important for both Supplier and Customer. MO²GO contains export and import mechanisms for partial models, as well as the possibility to define a master model. Projects can be processed independently and later brought together to one complete model. The tool enables one to reuse partial models and provides libraries with reference models.

The integrated and strong process-oriented approach helped to identify and prevent gaps in the current AIAG IV&I specification in terms of missing process steps and message specification to support the entire *Control* flow. According to eKanban specification, the *Production order* element, that initiates *Control* flow, is directly assigned to *Communicate consumed Kanban* without any information about Kanban container status. Missing information about necessary pre-condition that Kanban container is empty is obvious. To solve this problem, *Control* and *Material* flows are integrated with the help of transient connection elements. Feedback loops, according to the pick up material, were included additionally.

6 Next steps

Future work is planned in several directions. We plan to use the experience and results from the validation interviews (to be completed with the domain business analysts' involvement) to develop a structured test specification for the analysis of the consistency and completeness of the models created. Such a structured test specification will allow easier validation planning of enterprise modelling results in the context of cross-enterprise interoperable data exchange development.

Another planned activity is validation of the POP* meta-model. For the purpose of illustrating the potential use of the POP* meta-model in a cross-organizational setting, the partial model exchange between MO²GO, ARIS, and METIS tools with their corresponding EMLs will be performed. In particular, to indicate the potential use and usefulness of POP*, its application in practice is necessary. This requires mappings between POP* and each of the participating EMLs to be defined and possible ambiguities and inconsistencies identified.

Another future challenge is to use the identified data exchange requirements at the EM level to assist in creating messaging data models and, eventually, the XML Schema definitions for implementation of eKanban-conformant data interfaces. This capability could help drive efficiency and quality of real implementations of the interoperable interfaces with all technical details included. To that effect, we will investigate the *Basic architecture reference model* that is part of the ATHENA Interoperability framework (AIF) [15].

7 Conclusion

In this paper, we demonstrated that a well-structured IV&I Reference Model is an important ingredient to a successful conduct of a cross-enterprise eKanban business process validation. The IEM Method turned out to be a very efficient means for this purpose, allowing capture of eKanban business requirements in a simple and comprehensive way. The most important benefits of the selected approach are the strong support to implement eKanban based on the integration of operational processes to execute eKanban control, and the structures and processes to establish the connection and collaboration between partners. Here, the integrated specifications that are used in the eKanban execution, ensure common understanding between all stakeholders and consistency of data and processes.

The POP* methodology is a first attempt to provide a sound basis for model-based interoperability between collaborating enterprises. In the next period, we will be part of the community to improve and further develop the POP* methodology.

We expect that our validation of POP*-based partial model exchange will contribute to identifying and preventing possible or hidden weaknesses of the methodology like redundancies, inconsistencies and lack of expressiveness.

Disclaimer: Certain commercial software products are identified in this paper. These products were used only for demonstration purposes. This use does not imply approval or endorsement by NIST, nor does it imply these products are necessarily the best available for the purpose.

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