Pragmatic PLM process interoperability for aeronautic, space and defence DMN

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Pragmatic PLM Process Interoperability for Aeronautic, Space and Defence DMN

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Abstract.
Today, in order to confront the growing complexity of products and organisations, Aeronautic, Space and Defence (ASD) manufacturing enterprises are using more and more System Engineering, Product Lifecycle Management and Computer Aided Solutions for various engineering and management activities. Combined with a more and more important outsourcing, such trends led to the emergence of what is called Dynamic Manufacturing Networks (DMN). These DMNs are facing important difficulties for the establishment of PLM interoperability based on legacy PLM standards for Manufactured Product and Process data exchange, sharing and long term archiving. To address such issues, Airbus Group Innovations (AGI) has been developing a Federative Interoperability Framework (FIF) through iterations between research, operational and standardisation projects. FIF defines interoperability principles, brakes and enablers. Based on an analysis of DMN interoperability brakes and enablers, this paper proposes a new way based on FIF interoperability principles for dealing with pragmatic interoperability of PLM processes within the ASD digital business ecosystem. We propose a DMN interoperability conceptual framework, coupled with an experimental collaborative open platform (cPlatform), to achieve pragmatic PLM process interoperability. For this, we rely on DMN blueprint of PLM Business Processes developed within the frame of the IMAGINE project. The proposed approach is then assessed according to scientific, business and standardisation viewpoints.

Keywords. Interoperability, Dynamic Manufacturing Network, Product Lifecycle Management, Open Standards, Model based enterprise platform engineering

1 Introduction

Today, Aeronautic, Space and Defence manufacturing enterprises' products and organisations are more and more complex. It motivates usage of System Engineering, Product Life cycle Management (PLM) and computer aided solutions for engineering or management activities. Dynamic Manufacturing Networks (DMN) are then emerging, but facing important difficulties for the establishment of PLM interoperability based on legacy PLM standards for Manufactured Product and Process data exchange, sharing and long term archiving. Extending a Federative Interoperability Framework (FIF) developed by Airbus Group

Innovations (AGI) through iterations between research, operational and standardisation projects. Based on an analysis of interoperability brakes and enablers, this paper proposes a new way based on FIF interoperability principles for dealing with pragmatic interoperability of PLM processes within the Aeronautic, Space and Defence digital business ecosystem. The proposed approach addresses scientific gaps identified from an analysis of the state of the art. A first gap is related to the boundaries existing between research fields addressing process interoperability, which should work together if willing to achieve the expected interoperability. It concerns fields such as Business Process interoperability, Application interoperability, Information and Communication Technologies (ICT) interoperability, Enterprise interoperability and PLM interoperability. We address this gap by aggregating interoperability framework of these fields through the FIF. A second gap is related to boundaries existing between research activities based on common classifications of interoperability. A first classification distinguishes data, service and process interoperability. A second one distinguishes semantic and structural interoperability. A third one distinguishes prepared, built and operational interoperability. Finally, research on interoperability is often making abstraction of the systems to consider (generic research) and of the legacy systems (disruptive research). As a consequence, the results are very difficult or even impossible to apply. Indeed, they imply very important changes, huge investments and no evidence concerning creation of value for Aerospace & Defence industries or mitigation of risks concerning interruption of operations. This led us to propose and to develop the DMN interoperability conceptual framework, which relies on usage of an experimental collaborative open platform (cPlatform). cPlatform is used for demonstrating that the proposed approach for achieving interoperability of a DMN works at an acceptable price (effective interoperability) through simulation of DMN collaboration (pragmatic interoperability). The focus here is on building PLM process interoperability within a DMN context. For this, we rely on Business Process blueprint templates, a blueprint model being set of the different PLM process representations required for establishing interoperability. A DMN blueprint is an extended hyper-model for interoperability as defined by FIF.

This paper presents, based on an aeronautic use case, how to model a targeted DMN as a model based on aggregation of DMN blueprints defined from DMN templates, and the derived DMN platform which aims at simulating and demonstrating interoperability when applying appropriately a set of principles, rules and methods for preparing and building interoperability. The proposed approach is then assessed according to scientific, business and standardisation viewpoints.

1.1 Some definitions

In this paper, the PLM definition is the one provided by CIMDATA (c.f. http://www.cimdata.com/en/resources/about-plm): "*a strategic business approach that applies a consistent set of business solutions that support the collaborative creation, management, dissemination, and use of product definition information within the extended enterprise (customers, design and supply partners, etc.),* *spanning from concept to end of life of a product or plant and integrating people, processes, business systems, and information".*

DMN is defined, according to [1] and to [2], as "*a coalition, either permanent or temporal, comprising production systems of geographically dispersed small and medium enterprises and/or Original Equipment Manufacturers (OEM) that collaborate in a shared value-chain to conduct joint manufacturing*."

For System Engineering (SE) definition we rely on the definition given by the International Council on Systems Engineering (INCOSE) (c.f. http://www.incose.org/AboutSE/WhatIsSE): "*Systems Engineering is an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem. Systems engineering integrates all the disciplines and specialty groups into a team effort forming a structured development process that proceeds from concept to production to operation. Systems Engineering considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user need*".

1.2 The business context

In ASD domain's DMNs, due to adoption of PLM and SE, Product & Process Data (P&PD) needs to be exchanged not only between production systems, but also between design, production, support and operational environment systems. It is reinforced by the fact that OEMs are subcontracting not only production, but also design and maintenance of the Product components they are integrating. Percentage of subcontracting may reach more than 60 percent. These DMNs, even when restricted to the design process, are facing important difficulties for the establishment of PLM interoperability based on legacy PLM standards for Manufactured Product and Process data exchange, sharing and long term archiving. These difficulties are due to:

- The heterogeneity of PLM maturity and Interoperability maturity of the DMN members.
- The competition of PLM standardization initiatives and to the division of the Manufacturing and System Engineering stakeholders that are launching or supporting many different and overlapping standardization initiatives, reducing consequently the interest of such standards as it fragments the market and reduces the business value of implementing those standards.
- The existence of brakes for having PLM software solution providers implementing these standards to facilitate building interoperable collaborative enterprise information systems.
- Missing processes and methods within many enterprises for governing the evolution of the Information Systems in order to align enterprise motivations, PLM and SE business processes, Technical Information

Systems and associated ICT. Such governance should preserve the previous investments and limit the risks associated with the changes.

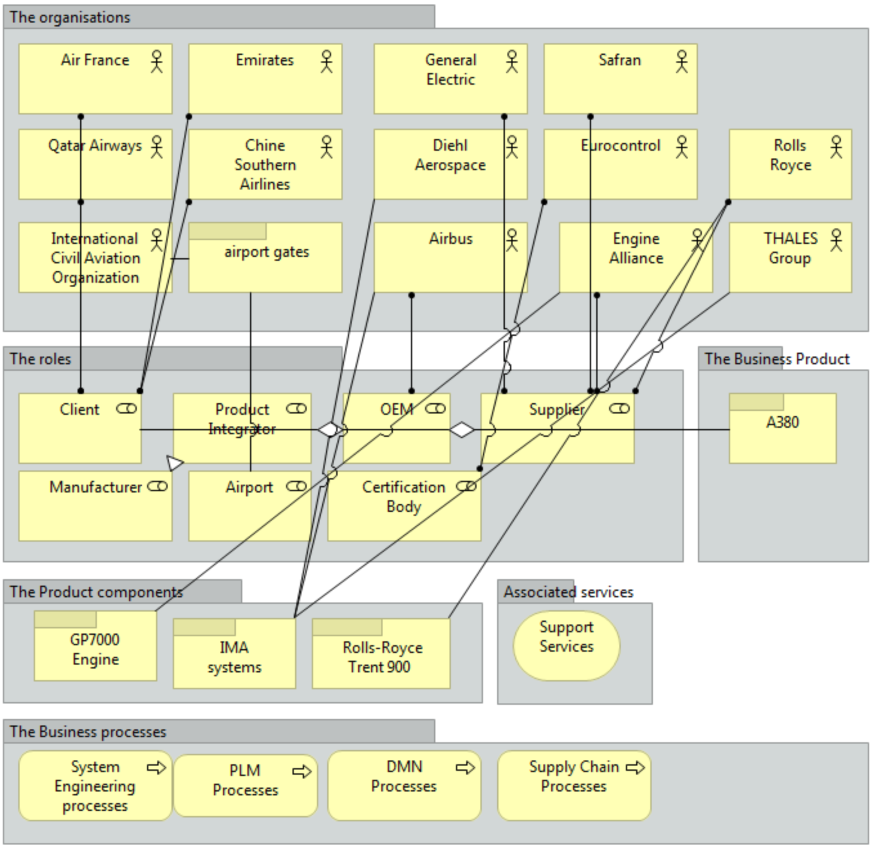

Figure 1: A partial A350 DMN view

In such a situation, many enterprises freeze the manufacturing program supporting information system when it starts, despite the fact manufacturing program duration can be longer than 20 years. As a consequence, information systems supporting industrial programs are often monolithic and subject to obsolescence. In addition, when several industrial programs exist within a company, numerous solutions and technologies co-exist within the enterprise. It leads to an over-complex information system following a model qualified as "spaghetti" model by the Gartner Group. Such information system is difficult to rationalize. Its evolution and maintenance is very costly. Finally it provides no agility to the organization, preventing innovation and creating a high risk for obsolescence. Of course, change is not a goal, but a means for organization remaining competitive, and risks associated to changes, in particular stopping the operations, are also to be mitigated. It can be achieved only by relying on flexible architecture supporting fast and efficient reconfiguration, and by promoting controlled urbanism of Information System based on enterprise modelling.

1.3 An illustrative example

In order to provide concrete examples in this paper, we rely on the case of A350 program. From publicly available description on the Web, we modelled the DMN using ArchImate standardized language and the Archi modelling tool. A DMN meta-model is used, which captures some of the actors involved in this program, with some of the important roles to consider within such a DMN: Original Equipment Manufacturer (OEM), which is an industrial integrator, product component providers (sub-contractor, equipment provider or risk sharing partner), clients (using the manufactured product to deliver a transportation service), infrastructure providers (*e.g*. Airports), component providers for the infrastructure (*e.g*. gate providers), maintenance service providers and finally certification organizations. Similar roles exist in other industrial domains, being for transportation or not. Figure 1 is a partial representation of A350 DMN and associate meta-model.

1.4 The standardization context

The last years, strategic importance of PLM standards was identified by main ASD players. It led to the creation of the Strategic Standardization Group (SSG [3]) at ASD European association, for which counterparts exist in other places (AIA in US) or for other industrial domains (*e.g*. VDA for automotive). The mission of ASD SSG is to survey the relevant standards to support eBusiness PLM collaboration for European ASD. ASD SSG tools are the Radar chart (*c.f.* Figure 2) for display of adopted, candidate and tracked standards, and an interoperability framework.

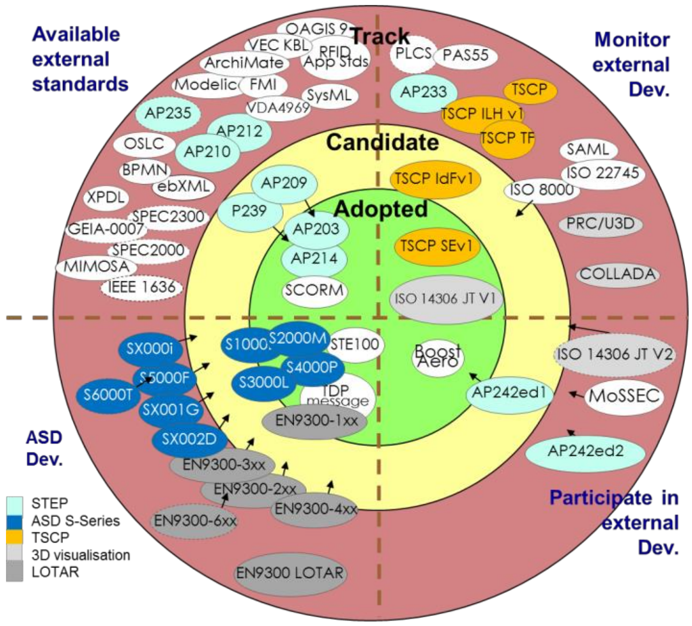

Figure 2: ASD SSG Radar Screen

As reflected by the radar screen, most important standards include those related to manufacturing data, and developed under the umbrella of ISO TC184 SC4. Several standardization projects were pushed by ASD SSG, as the merging of Automotive' AP214 "core data for automotive mechanical processes" and Aerospace'AP203 "Configuration controlled 3D Design" in the modular AP242 "Managed Model based 3D Engineering". In order to ensure the Through Life Cycle Interoperability (c.f. "ASD SSG Through Life Cycle Interoperability report" on [3], ASD SSG also pushed the convergence between AP242 and AP239 and the set-up of PDM and PLM implementor forums (*c.f.* "PDM IF" white paper presentation on [3]).
Several standards related to process modelling are tracked including Wfmc's XML Process Description Language (XPDL [5]) and Object Management Group (OMG) Business Process Model and Notation (BPMN [6]). Unlike currently adopted standards, which also allow capturing description of processes by means of shared STEP modules, they are not Product Data Exchange and Sharing centric, but aim at describing or modelling collaborative processes which can eventually be executed by workflow systems. Other tracked or untracked standards allow capturing and representing processes. It is the case of SysML [7], with Activity Diagrams, or UML [8], on top of which SysML is built as a profile. It is also the case of OMG' Software and Systems Process Engineering Metamodel Specification (SPEM [9]) which allows capturing configured sets of versioned practices in order to model a methodology. Finally, the Open Group's ArchImate standard [10] provides an enterprise modelling language, which viewpoints dedicated to the formalization of business processes, and how they are supported by applications realized by different Information and Communication technologies.

Other standards to consider are those delivering standardized process descriptions, such as ISO/IEC 15288:2008 Systems and software engineering – System Lifecycle processes [11], which give a frame for enterprise willing to put in place such processes.

All these standards have been developed by heterogeneous communities, having different usage and objectives in mind, and aiming at covering different needs. As a consequence, they were not designed in order to be used together, but all can be used simultaneously within a DMN in order realizing PLM solutions. That creates some PLM interoperability issues to be resolved if willing to support effectively DMN collaboration.

1.5 Research context

The last ten years, in order to address PLM Interoperability, Airbus Group Innovations (AGI) have been developing a Federative Interoperability Framework (FIF). It was done through iterations between research, operational and standardisation projects which gave collaboration opportunities to the authors of this paper. FIF first formalisation was provided in a thesis concerning Interoperability of Technical Enterprise Applications [12], [13]. It describes a federated framework for interoperability of technical applications applied to networked collaborative product development, built through participation to or assessment of several research projects in PLM area (RISESTEP – Enterprise

Wide standard access to STEP distributed databases -Esprit Project 20459), SAVE (Step in a virtual enterprise - bright euram project 97-5073), OpenDevFactory (Paris cluster Usine Logicielle 2006-2009), CRESCENDO (FP7 Transport 234344 Collaborative and robust engineering using simulation capability enabling next design optimization), TOICA (Thermal Overall Integrated Conception of Aircraft), SIP@SystemX, Factory of the future area (IMAGINE FoF ICT 2011 7 3 Innovative end to end management of dynamic manufacturing networks), in enterprise application interoperability area (IDEAS IST 2001 37368, ATHENA FP6 IST 507849 Advanced technologies for interoperability of heterogeneous enterprise networks and their applications - COIN Collaboration and interoperability for networked enterprises IST FP7 IST IP project 216256, NEFFICS Networked enterprise transformation and resource management in future internet enabled innovation cloud FP7 ICT 258076) or in Digital Business Ecosystems (FP6 Integrated Project IST-2002-507953) area.

Research presented in this paper is based on the usage of the principles defined by the FIF, and extends it in order dealing with pragmatic interoperability of PLM processes within the Aeronautic, Space and Defence digital business ecosystem. FIF aims at the effective establishment of interoperability by federating interoperability frameworks and mature legacy open standards. It promotes governing the standards for establishing required interoperability maturity, as it is the case today for ASD with ASD SSG. It also promotes such a governance harmonizing operational, research and standardisation projects of the different concerned communities, in order to achieve the targeted continuous interoperability. Such an approach is illustrated by the business, standardisation and research context descriptions provided in this section.

1.6 DMN commodities on the Web

The different research, standardization and operational projects allowed assessment of the maturity of technologies associated with the considered standards related to process models, process modelling and process execution, which can support an effective way for the establishment of PLM interoperability within a DMN. One principle defined by the FIF is the selection of standards which are mature enough, *i.e*. for which several implementations exist, including commodities on the Web. Commodities on the web are defined as freely available software solutions, which are open source and implement open standards. A standard can be an interoperability enabler only at this condition. We realized assessment of process modelling standards which can impact establishment of PLM interoperability within a DMN, and elected BPMN, XPDL, SPEM and ArchiMate. For all these standards (with detailed references provided on ASD Web site blips), we identified commodities on the Web and established their maturity.

Table 1 shows for each standard the identified solutions which can be used as building blocks of a DMN hub and DMN applicative nodes. These blocks will complete those of the cPlatfom, which already integrate an Enterprise portal based on portlet standards, an Enterprise Service Bus based on Web services standards, and Product Data repositories based on data exchange and sharing standards, being

STEP technologies, XML technologies, RDF-XML technologies or Ajax technologies.

Table 1. Solutions for a DMN hub and DMN applicative nodes.

Application	Standard	Solution	Comment
Workflow modeller	Wfmc Standards architecture of reference - XPDL	Together Workflow Modeller (Jawe)	Numerous other commercial modellers are implementing import and export in XPDL
Workflow engine	Wfmc Standards structured according architecture of reference – XPDL, WAPI	Together Workflow Server (Shark)	Numerous commercial workflow engine support or can support import/export in XPDL
Method modeller	SPEM	Eclipse Process Framework (EPF)	UML modeller supporting UML profiles can also be used, but does not support necessarily publishing
Method publisher	SPEM	EPF	Any generator which can be created from UML modelling environment
Enterprise modelling	ArchiMate	Archi	ArchiMate are also supported by drawing tools (e.g. Visio stencils), UML modellers (ArchiMate profiles) and numerous Enterprise Modelling commercial platforms

1.7 The addressed problem

The problem addressed by the research activity leading to the results presented in this paper is related to pragmatic PLM Process Interoperability for Aeronautic, Space and Defence DMNs. Considering legacy PLM standards used by ASD community, existence of multiple process descriptions, relying on a set of heterogeneous and not aligned descriptions, modelling languages or execution languages, create important interoperability issue. The next state of the art section, resulting from studying if and how such an issue is addressed by literature, introduces the new approach we propose.

2 The state of the art

Several issues were identified from the analysis of literature on process interoperability. A first issue is related to the boundaries existing between research fields addressing process interoperability, which should work together if willing to achieve the expected DMN interoperability. It concerns fields such as Business Process interoperability, Application interoperability, Information and Communication Technologies (ICT) interoperability, Enterprise interoperability and PLM interoperability. Interrelating the different fields was nevertheless very often stressed. Proposing taxonomy for workflow management (WFMA) interoperability, [13] clarifies what interoperability means for WFMA. First communication between individuals and/or systems is to be established with the intention to reach an objective in an optimal way. It relies on common system of symbols, signs and behaviour. Then coordination is to be established, by organizing activities between several interdependent persons and/or systems, on top of the communication system. Collaboration will occur, consisting in partners acting jointly for intellectual efforts. Interoperability can be considered as inter-organizational collaboration where workflow takes control of coordination. Networking ability is denoted as the ability to rapidly and efficiently implement, settle and enhanced IT based relationship. [13] proposes a methodology for development of an interoperable and flexible workflow management. The limitation we identified, comes from the fact interoperability is restricted to WFMA only, without considering impact of Product & Process data architecture and Enterprise Architecture. This issue was addressed by the FIF [12] by aggregating several fields such as SE, Enterprise Modelling, Enterprise Application Integration and Model Based Software Engineering in order to contribute to Networked Collaborative Product Development. But the FIF is still to address process interoperability at the scale of a DMN.

A second issue is related to boundaries existing between research activities based on common classifications of interoperability. A first classification distinguishes data, service and process interoperability. A second classification distinguishes semantic and structural interoperability. A third classification distinguishes prepared, built and operational interoperability.

The FIF addresses this second issue by federating different interoperability frameworks in order to characterise the ideal collaborative system for networked collaborative development [12]. Semantic preservation is addressed by the FIF for product data through extended hypermodel for interoperability [15], but not yet for process data semantic preservation. Comparison between different workflow languages has been addressed through workflow patterns [16], [17]. Workflow patterns provide a conceptual basis for assessing the suitability of workflow languages or business process modelling language for supporting process-aware information systems. Such assessment allowed comparing workflow and business process modelling languages and workflow applications, pointing out that some languages are less precise than others. E.g. one XPDL representation of a workflow can be represented by seven different representations of the same workflow with Petri Nets, with different behaviours when interpreted by a software system. It means that the XPDL representation of the workflow process alone is insufficient for characterizing the behaviour of a workflow system when executed. The workflow system is to be known. When willing to prepare and construct operational interoperability, it means using standardized workflow and business process modelling languages is insufficient, the underlying execution systems are to be characterized and qualified. It is the reason why FIF relies on an MDA approach with specifications and qualification rules of an execution platform. So far, FIF has not yet specified and qualified the cPlaform components for enterprise modelling, product data management, business process modelling and workflow systems in a way they ensure pragmatic process interoperability.

A third issue is related to interconnection of workflow systems. [14] does not address the situation where multiple legacy WFMA have to be interconnected, implying the coupling of the business processes and derived workflow processes enacted by several workflow systems. At ICT layer, if Wfmc architecture of reference identified the interface between workflow engines, Wfmc community failed so far producing a specification that can be adopted by the market. At the business layer, cooperation between workflows was investigated by Coopflow [18]. Coopflow implementation based on Petri Nets is proposed. But Petri Nets are not used by Wfmc's Enterprise workflow standards, as they are not suited for easy capture of business logic by business analyst. More suitable for extending the FIF, [19], [20] define CoopFlow framework for ascending workflow cooperation within virtual enterprise. This framework proposes an abstraction of workflows which distinguishes internal workflow, cooperative workflow and interconnection of cooperative workflows. If CoopFlow platform cannot be integrated on the cPlatform, as it is not based on an open standard and as it is not a software product, the abstraction proposed by CoopFlow is very relevant in order to address interconnection of the workflow systems of a DMN participants through a DMN platform which will act as a mediator between information systems and processes of each DMN participants. One open question is how to aggregate such abstraction in FIF for supporting DMN collaboration.

So the scientific objectives of the research activity that led to the proposal we detail in the next sections are the extension of the FIF to support pragmatic process interoperability for Aeronautic, Space and Defence DMNs. It should address the three issues identified through analysis of the literature:

- Boundaries leading to non-interoperability between WFMA, PLM, SE, Enterprise Architecture, Enterprise Application and ICT fields
- Boundaries leading to non-interoperability between the different interoperability frameworks addressing different kinds of interoperability and relying on heterogeneous classifications
- Interconnection of workflow systems and business processes of the DMN members relying on commodities on the web related to the PLM standards elected by the ASD community
- Effective combined usage of a configured and consistent set of ICT, WFMA, Enterprise Modelling SE and PLM standards in order to prepare and to build operational interoperability within a DMN.

For this, we propose a DMN interoperability conceptual framework, coupled with an experimental collaborative open platform (cPlatform), in order to achieve pragmatic PLM process interoperability. Figure 3 shows the objective of research activity presented in this paper, how DMN interoperability conceptual framework is related to FIF and cPlatform. It also makes a clear link with the need of supporting collaborations in an ASD DMN, and with the scientific issues identified in the state of the art analysis.

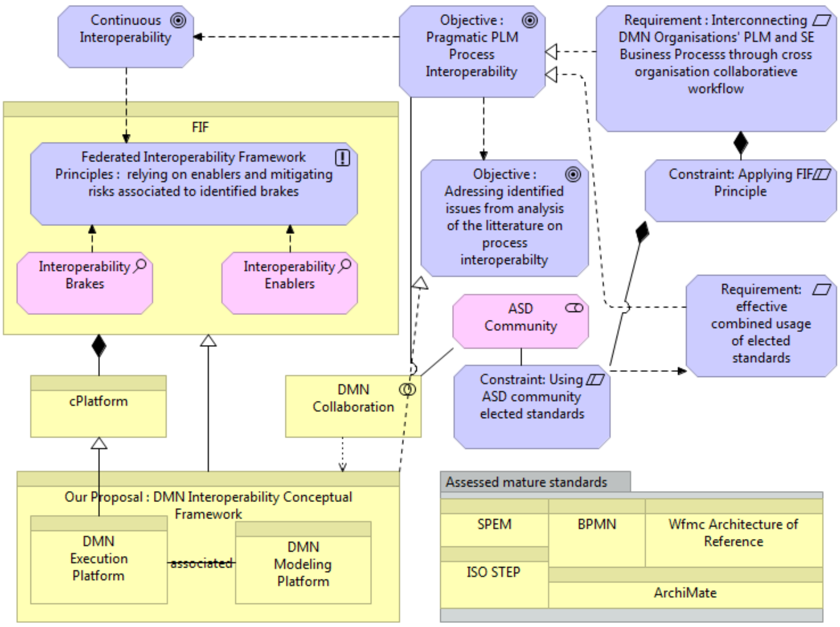

Figure 3: Presented research activity objectives modelled with ArchiMate

3 The DMN interoperability framework

In this section, we introduce the DMN Interoperability Framework. DMN Interoperability has been described in several other papers, but without the focus on pragmatic process interoperability. This framework introduces the usage of DMN blueprints based on ArchiMate and modelled with Archi, which we formalized through the IMAGINE Aerospace & Defence Living Lab.

3.1 About usage of AchiMate and Archi

ArchImate choice is the application of the FIF principles concerning the usage of enterprise modelling as an enabler for building interoperability and of open mature standards for preparing the interoperability. Archi choice is the application of the FIF principles concerning the importance of open source for interoperability and usage of Model Driven Architecture as an enabler for building the interoperability in an effective way. Archi is indeed an open source free solution of industrial quality, built on top of Eclipse Modelling Tools (EMT) and on top of Eclipse platform, with EMT implementing OMG specifications related to Model Driven Architecture (MDA). Finally, Archi is an implementation of reference of the whole ArchImate specifications, including not only the language but also usage of views built according a set of viewpoints predefined by the specifications, and addressing communication needs with a set of predefined stakeholders, which are not necessarily experts familiar with modelling.

An extra motivation for selection of ArchiMate and Archi, which is directly related to DMN interoperability and was not captured in FIF principles, comes from the fact ArchiMate modelling language is a simple language with very few modelling constructs (about 50, when more than 250 exist for UML or SysML, and about 150 for BPMN), links can be easily made with Domain Specific Languages (DSL) and associated modelling languages of the different architects and experts for ICT, Information System, Data Structure, Business process and service Modelling, Project Management or Business Architect. That makes Archi and ArchiMate perfect candidates for supporting controlled urbanism of the DMN infrastructure, and driving the evolution through change management based on motivation analysis, value creation and mitigation of risks associated to continuous evolution of business processes and ICT technologies.

Archi and ArchiMate were consequently selected as a way for implementing the DMN modelling platform represented in Figure 3. As the modelling constructs of ArchiMate are very closed to the conceptual models of Enterprise applications, such as Enterprise portal, Enterprise Service Bus or Enterprise Workflow, which are building blocks of the cPlatform according FIT principles, communication can be easily established between DMN designers and DMN operators on the basis of Model Transformation information exchange.

The risk concerning locking by Archi Software provider or ArchiMate community is mitigated by the DMN architecture, which is component based. Replacement of ArchImate by another standard for enterprise modelling or Archi by another software product will not impact the DMN Execution platform, and have limited impact on the DMN methodology.

3.2 The DMN concepts extended for Process Interoperability

The different DMN concepts defined here are those depicted in Figure 3**,** with in addition rules to be followed in order DMN supporting effective process interoperability**.**

Dynamic Manufacturing Network (DMN): DMN is a network of partners implied in the collaborative development of a manufactured product, with associated applications supporting PLM process, System Engineering processes and controlled urbanization of Information system, with the solutions realizing the applications.

DMN Execution Platform: it is a cross-organizational collaborative enterprise platform which acts as a DMN hub between the partners working on a given product, their extended enterprise processes, the applications supporting these processes and the technologies which realize the applications. As a PLM hub, this hub is used for secured transportation of Product and Process data, and provides different services related to standard based exchange, sharing and linking of Product and Process data, and associated supporting systems (for design, production, operation or support).

DMN Modelling Platform: it is a visual enterprise modelling platform, relying on an enterprise visual modelling language. Such an enterprise modelling platform must allow capture and presentation of interrelated motivation, business, applications and technologies, through usage of views structured according as set of predefined viewpoints. The viewpoints are associated to DMN participants and their concerns for supporting System Engineering, PLM and controlled urbanization of Information system in a consistent way. In particular PLM processes, viewpoints associated to data architecture and Controlled urbanization processes must be consistent.

DMN Workflow System: it is an enterprise workflow system, which must be extended in order being able capturing expected characteristics of participants of a cross-organizational workflow model, capturing the characteristics of actual DMN members which are plugged on the hub, comparing them and reporting when expected and actual characteristics do not match.

<u>Rule 1</u>: the DMN Workflow System is structured according to the Wfmc Architecture of reference.

<u>Rule 2</u>: the DMN workflow system must be based on the DMN elected workflow language.

DMN Platform Designer: it is a software design platform that must be able to consume models coming from the DMN modelling platform, and extend them in order to provide PIM and PSM models that will be used for generation of artefacts that will be deployed on the DMN execution platform.

<u>Rule 3</u>: the DMN Platform Designer must support generation of DMN execution artefact targeting the DMN workflow execution system.

DMN Development Platform: it is a development platform that allows developing and deploying the different artefacts of a DMN execution platform from the DMN blueprints.

<u>Rule 4</u>: DMN Development Platform must include a studio for modification of the workflow when required, for its validation, for its packaging and for its deployment on the DMN execution platform.

DMN Engineering Platform: it is the applicative infrastructure for the creation of an interoperable DMN environment, combining the DMN platform designer, the DMN development platform, the DMN modelling platform, the DMN workflow system, the DMN execution platform, structured as a DMN software factory.

<u>Rule 5</u>: the DMN platform designer should support communication with the different DSLs related to business collaboration and business process, and interchange with Domain Specific Meta-languages supporting formalization of business and application collaborations for support of workflows and ASD Manufactured Product & Processes data exchange.

DMN Information Structure viewpoint: It is a viewpoint comparable to the traditional information models created in the development of almost any information system. It shows the structure of the information used in the DMN organizations, in the PLM/Urbanization/SE business process and in supporting application and technologies. Stakeholders are Manufacturing Product and Process Data architects. The concern is the consistency, completeness and accuracy of data models and of Domain Specific Languages used in the DMN and by the DSF. It includes DSL and models provided by manufacturing, enterprise, business, applicative and ICT standards constituting the FIF applied to a given DMN.

Rule 6: Information Structure viewpoint must be structured according a set of DMN Collaboration and Process blueprints capturing the different representations of DMN collaborations and Processes to be supported within the DMN. It includes Domain Specific Meta Language associated to the ASD DMN elected standards (IDEF0[21], SysML, EXPRESS[22], XML Schema[23], and OWL2[24]) and to the best candidates identified using FIF methodology and principles, *i.e.* ArchImate, BPMN, XPDL, WSDL[25], UML, Java[26], and OWL2[24].

DMN Software Factory: it is an organization of a DMN Engineering platform aiming at taking advantage of Model Driven Architecture and Model Driven Engineering and realized through the usage of qualified model transformation capabilities based on open standards.

Rule 7: meta modelling capabilities based on MOF should be made available on the software factory for the different needed transformation, being software component of the DMN platform, artefacts to be deployed on the DMN platform, or ASD Manufactured Product & Process data realizing any kind of representation, including Computer Aided specification, design, manufacturing and support models, but also Manufactured Product & Process management metadata (*e.g.* Product Data Management – PDM – or Enterprise Resource Planning – ERP).

DMN blueprint: it is a model of one or several nodes of a DMN. It is formalized first in ArchiMate) as a data object (application layer), realizing a business object which can be described using various representations, being active, passive or behavioural (as defined in ArchiMate 2.1). It is consequently an extended hypermodel for interoperability as defined by FIF. Many realizations of a DMN blueprint exist at different places of the DMN infrastructure (ICT layer of the DMN). The list of nodes for which a DMN blueprint could be defined includes Manufactured Products, Private Business Processes, Business Services, Cross-organizational Business processes, Organizations, Projects, Personal, Process segment, Configuration items, Methods, Applications, Software Systems, Devices, Networks, Plants, etc. Concerned Business Processes are PLM and SE processes. Concerned cross-organizational collaborative processes are primarily change and configuration management processes.

Rule 8: A set of blueprint templates of reference must be provided in order to support the consistent usage of the different representations of PLM, SE, Standardization and Controlled Urbanization processes within a DMN.

Rule 9: Blueprints models of the elected standardized processes (*e.g.* for potential candidates: ISO 15288, SCOR), with all the realization which have to be supported with the different elected languages (*e.g.* ArchiMate Business Process View, and XPDL model of ISO 15288).

3.3 The DMN Blueprint templates and Process Interoperability

DMN methodology, as defined in IMAGINE, proposes a set of blueprint templates for any kind of DMN nodes. Figure 4 shows a DMN Business Object Information template.

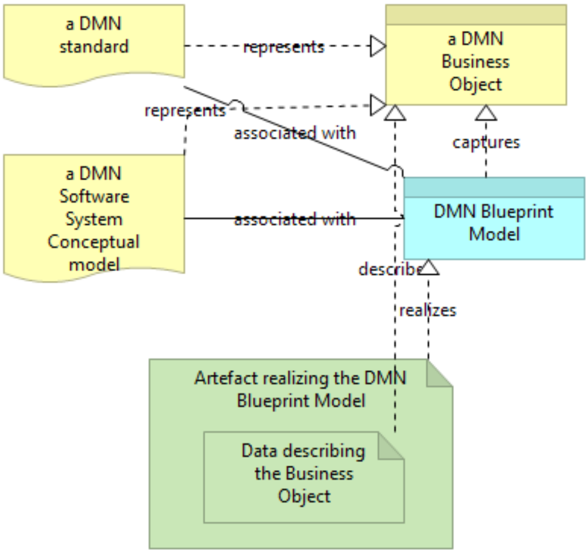

Figure 4: DMN Business Object Information template (T1)

In order to support communication within the DMN which supports exchange of DMN collaborations and DMN processes representations, we experimented using this template to include several business process representations based on languages related to standardized processes and those related to process or collaboration representations. It was done for a set of ASD and FIF elected standards. Producing the blueprints was guided by the analysis and assessment of those standards, in terms of intended usage, being used by an organization, a discipline or an application. It was also guided by the needs of transformations to be realized in order supporting DMN collaboration and PLM processes within the context of ASD System Engineering.

Figure 5 illustrates the building of a DMN Business Process blueprint with business, application and ICT representation related to ArchiMate and XPDL standards. Several ways of capturing a DMN business process (as a business object) were considered:

- A model element in ArchiMate model formalized as an ArchiMate: Business Process modelling construct.
- An ArchiMate view based on ArchiMate organization viewpoint, which is a subset of an ArchiMate model.
- An Archi file (.archimate) which is based on XML and on a schema defined by Archi.
- A process workflow model, which can be represented using XPDL, with BPMN as notation and XML as the syntax of the files used by the ICT solutions chosen for the realization of the workflow system(Shark and Jawe)

On the example, a DMN Participant blueprint is also introduced. We can see that such participant will be formalized as a workflow participant in XPDL, with different types: role, person, organization or applications. These roles will correspond to several business objects in Archi, with a set of associated representations, *e.g*. an ArchiMate business actor can be as well a person, a group or an organization. An organization can also be represented by means of an ArchiMate view based on ArchiMate organization viewpoint.

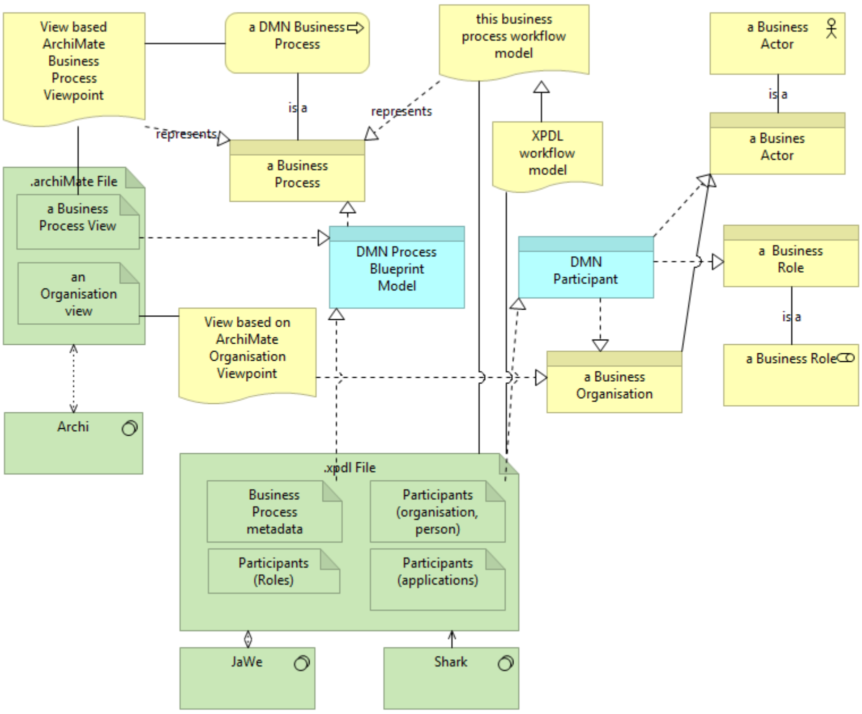

Figure 5: Building Process blueprint for ArchiMate and XPDL

This experimentation demonstrates that it is not possible to define a DMN blueprint by relying on mappings between modelling constructs of languages. Different granularity levels exist and should be managed. For example, a business process can be captured as an ArchiMate Business Process model element, and as a more detailed view based on ArchiMate Business Process viewpoints. This allows its description with a set of elements that are themselves model elements typed as interrelated ArchImate Business Process, Actors, Roles, Collaboration, *etc*.

Similarly, the same elementary business process can be represented by means of models: collaboration (ArchiMate, BPMN), orchestration (ArchiMate, BPMN, XPDL, UML Activity diagram), choreography (BPMN) and data flow (IDEF0, BPMN).

Being able to define required transformation to support either Product & Process data exchange in the DMN, or deployment of the business logic from the DMN modelling platform to the DMN execution platform, implies clarifying and architecting the different levels of granularity, and then associated transformations at the same layer (data to data transformation) or between layers (data to metadata,

metadata to data). Figure 6 illustrates such multi scales representation. For a given business process, "*my Business process*", two representations are available: one as a view based on ArchiMate Business Process Viewpoint, the other as a data flow between function, as done in IDEF0.

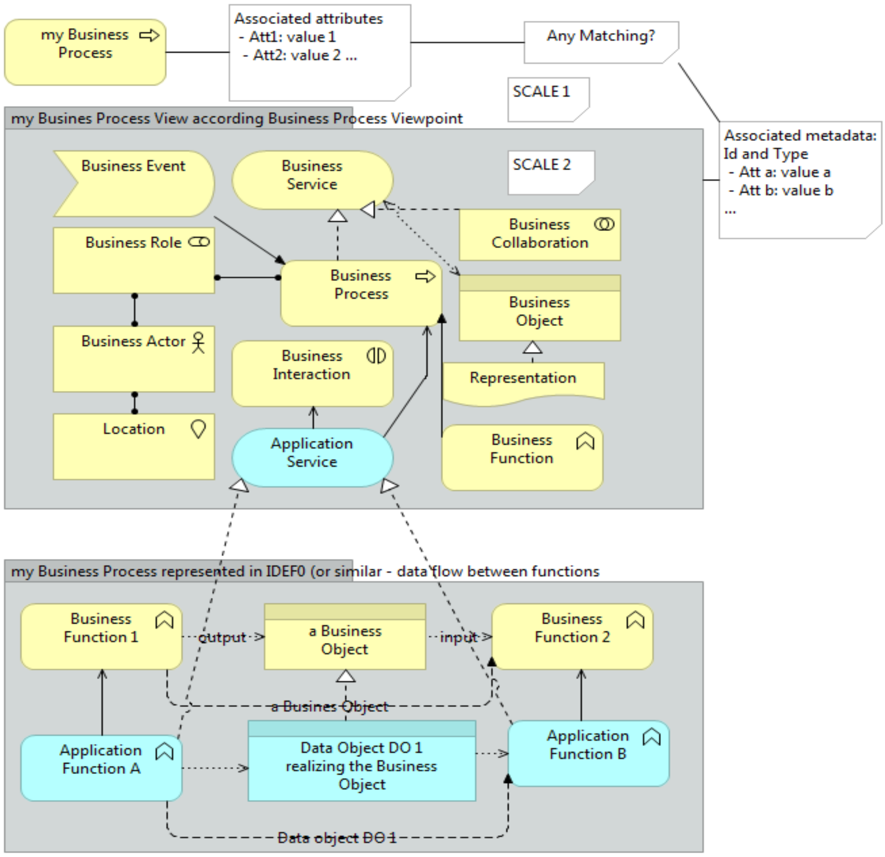

Figure 6: Multi Scale representations

Some attributes can be attached to "*my Business Process*", and metadata attached to the representations of scale 2 (Figure 6) describing also "*my Business Process*". Finally, the same business process can also be represented at scale 2, linked to lower layer model elements through composition or aggregation relationships. But composition/aggregation relationships are not necessarily suited for capturing multi-scale representations.

After identifying potential issues related to multi-scale representations, put in evidence through usage of DMN blueprints, we studied other potential impact of multi-scale representation for DMN process interoperability.

We identified that sub-flows captured with BPMN or XPDL, in order indicating that an activity will correspond to a sub-flow, *i.e*. to the launch of a workflow process model instance, cannot be formalized as a decomposition. This mechanism is linking an object typed at scale 1 (activity instance) to an object typed of scale 2 (workflow process instance) in terms of representation granularity. The process models themselves can be attached to the organizations owning them and running them, and organizations can be decomposed at different scales. Cross-organizational processes and organization internal processes are at different scales, leading to rely on escalation process. It means that something that can be resolved at a given level of organization must be addressed at an upper organization level, with change of scale in the decision process. In between, extended organization processes can also be formalized. Using such process implies some hierarchy between the organization owning the process and the other participants. It is the reason why they are often used in a client/provider context.

We also identified scale related issue when attempting producing DMN blueprints of STEP application protocols activity models, initially formalized in IDEF0, as a representation of a Business Process, and then making the link between information flows and Application Reference Model entities. The data objects which are input and output of functions captured using IDEF0 activities and the entities in the ARM are not represented at the same scale. It makes it about impossible mapping entities with data object of the Application Activity Model.

This section can be concluded summarizing what we achieved by applying DMN methodology practice consisting in producing a set of DMN blueprints based on ArchiMate and Archi. We demonstrated that language mapping is not sufficient to capture how multiple representations of a same business process are related. Several levels of granularity are to be considered, and lead to consider impact of multi-scale representations. Within a DMN, usage of multi-scale representation has an important impact when willing to build interoperability. The different scales which are used in the DMN must be structured according to architecture of reference. Such architecture of reference can be related to the classification of collaboration process distinguishing organization internal processes, collaboration processes extending an organization and cross-organizational processes. Such architecture will impact not only processes, but also information structure, in particular when considering information flows that can be formalized by means of a process representation using languages such as IDEF0, BPMN or Archi.

3.4 The DMN engineering platform and Process Interoperability

To support effective application collaboration within the DMN, with interconnection of workflow engines of the DMN participants through a cross organizational workflow system running cross organizational PLM collaboration processes, we experimented a realization of the DMN Engineering platform based on commodities on the web, implementing elected ASD SSG and FIF standards.

We produced a more detailed blueprint template capturing DMN workflow system and the experimented realization as illustrated in Figure 7. This template refines the roles in ASD collaboration, including OEM, integrator and product component provider roles. Collaboration is made around a configuration item, allowing the capture of specifications on the components and characteristics of the product realizing the component. For the cross-organizational change process, which is strongly connected to configuration management to keep product data under control, a contractual exchange convention is attached to a collaboration workflow model formalized in XPDL, CoopModel1. This model is designed with the DMN Platform cross-organizational workflow modelling application, then deployed and enacted in the workflow engine of the DMN Enterprise workflow system. The workflow relevant data are exchanged between the workflow engine and the workflow work list handlers of the workflow participants. The Technical Data Package (TPD) contains all data required by a participant to respond to a work order (change request, change order). Required packaging, transformation and data quality checking services to be realized by the DMN platform are not indicated as the focus is here on collaborative processes.

A first encountered issue for PLM process interoperability comes from the fact that standalone enterprise workflow systems are not dealing with data flows between applications, but only with data flows concerning workflow relevant data, exchanged between workflow engine and work list handlers. It also appears through the experimentation that the physical data flow can only be defined during the second level of runtime, when a task is accepted by an actual actor. It is only at this moment the precise location of the actor is known, as well as the application he will use in order to perform his task. As a consequence, the data flow to be realized cannot be defined from a process model defining data flow between activities which are also used for process orchestration. A first impact of this analysis is the identification of the need of a service, which will customize on the fly the realization of the manufactured Product & Process data flow. One direction that will be investigated in our future research activities will be the attachment to the task delivered by change management workflow activities of information allowing to access to input and output data locations, which will then allow to perform the transportation of these data. A second impact comes from the fact this experimentation demonstrated the accuracy of using IDEF0 for Application Activity Model (AAM) within the ISO STEP frame, and not a model capturing an orchestration. Using DMN methodology and associated blueprints, it should be easy demonstrating that AAM formalize in IDEF0, or through usage of accurate DMN process template based on functions and data flows, as illustrated in Figure 7, should be useable in order coupling workflow system services and previously described services for on the fly secured data transportation associated to qualified transformation.

A second encountered issue concerns how to produce DMN XPDL templates dedicated to the different categories of collaborative workflow processes. We identified that it can be achieved by appropriate usage of ArchiMate roles, actors, functions and applications properly mapped with XPDL workflow process classification. A cross-organizational process workflow model will be modelled with only participants corresponding to ArchiMate roles and functions. An extended organization process workflow model will be modelled the same way, excepted for the extended organization for which ArchiMate actor and application will be used.

Finally, for an organizational internal process, which is not multi scale and with a frozen organization, all the participant of the process workflow model will be actual actors and applications. The DMN workflow system will have to support mapping between roles and actual participant at the enactment time, after launching of an activity or from the work list handler. Finally, coupling between

DMN cross-organizational collaborative process workflow and extended enterprise collaboration workflow will be made at the task level, with percolation between higher level organization scale and lower level organization scale.

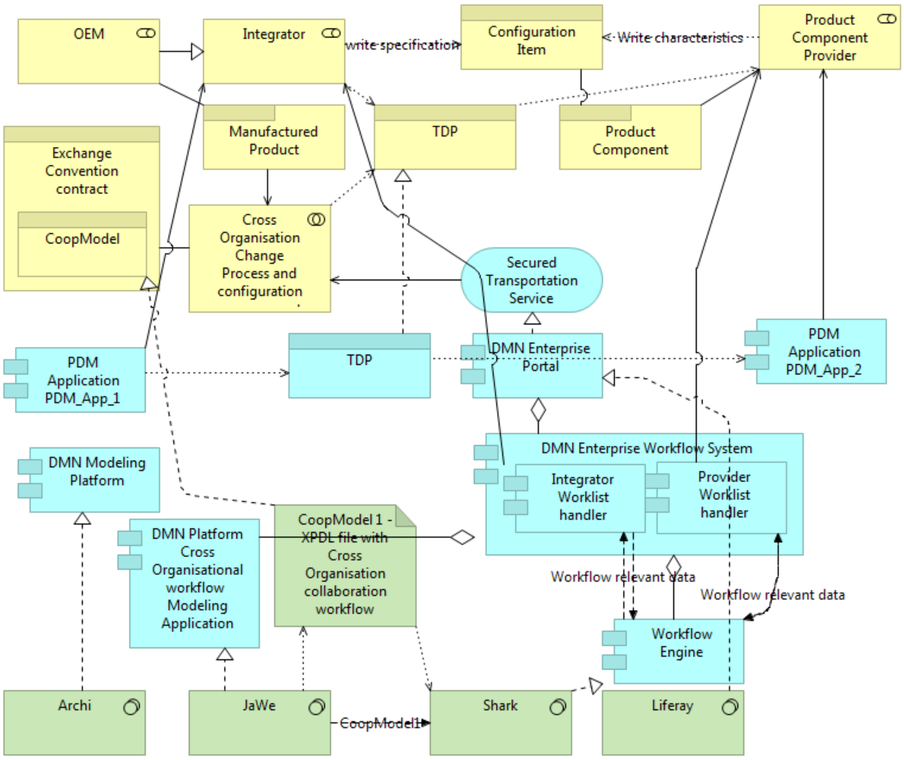

Figure 7: Cross-Organizational DMN workflow template

4 Conclusion

In this paper, we proposed a DMN interoperability conceptual framework, coupled with an experimental collaborative open platform (cPlatform) to achieve pragmatic PLM interoperability. For this, we rely on usage of the DMN methodology we defined in IMAGINE, formalizing process and collaboration blueprint to produce DMN blueprint within ASD PLM standardization context and applying FIF principles. We also studied extension of the cPlatform defined in IMAGINE in order to realize a DMN workflow system supporting the deployment of DMN process model artefact that can be generated from the DMN blueprint based on proposed templates. This realisation is also guided by the FIF and associated principles, based on assessment of enterprise technical applications interoperability enablers and brakes.

As a result, we demonstrated it is not possible relying on mappings between modelling constructs of languages in order to define a DMN blueprint. An architecture of reference is to be defined to deal with multi-scale collaboration, organization and data modelling if willing to achieve pragmatic PLM interoperability in an ASD DMN. We also demonstrated that realization of Manufactured Product & Process data flow by secured transportation, transformation and quality checking services cannot be defined from an orchestration model, but from process model representations with data flows between functions. These functions can be mapped with DMN participants by DMN workflow system as soon as tasks are attributed to actual participants.

The result will be exploited in research, operational and standardization projects. DMN methodology and platform will be assessed and extended in the Standard Interoperability Project at IRT-SystemX, to deal with assessment of PLM standards and their implementation. DMN blueprint modelled with Archi will be used to support Future Architecture of ISO TC184 SC4, to propose and assess evolution of the Manufacturing Data standardization framework, ensuring preservation of previous investment and reduction of risks associated to the proposed changed. Finally, methods and tools derived from DMN methodology will be proposed to improve the ASD SSG interoperability framework, for assessment of usage of a consistent set of configured open PLM standards.

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