Enterprise and Business Processes - How to Interoperate? The Standards View

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Abstract: Cooperation between and collaboration with partner organisations is a business requirement, which needs for its fulfillment a fast and easy exchange of information between the partners. Therefore interoperation between heterogeneous ICT systems is becoming a high priority requirement in such a global business enterprise environment. Numerous standards to support this interoperation have been or are developed by both Standards Development Organisations (SDOs) and industry consortia. However, with no coordination between the different organizations these standards are providing neither a coherent nor a sufficient set of solutions.
An overview of currently available and forthcoming standards is provided and some conclusions are drawn for the different potential solutions.

1 Introduction

The use of Information Technology (IT) in business enterprises lead to a plethora of business applications within enterprises and across industries. Coping with this great variety, both vendors and users have endeavoured to resolve the heterogeneity by interfacing and integrating the different applications into an operational system. Unfortunately, the results are only marginally effective due to the never ending evolution of such systems.

Enterprises today face an even more challenging problem brought about by business globalisation. This global environment has increased dramatically the needs for inter- and intra-organisational communication, coordination, cooperation and collaboration and even more importantly for us, the needs for adaptation to the different operational contexts of the cooperating and collaborating partners. Due to the limited time frames of such common efforts, the communication response times must be much shorter than in the past. The corresponding need for interoperation of the related IT-based business and technical processes has lead to huge R&D efforts in both academia and industry, which in turn has initiated numerous standardisation efforts in Standards Development Organisations (SDOs) and industry consortia.

Starting from work directed towards enterprise integration, with origins from the 70s and 80s of the last century, the focus in R&D and standardisation has shifted during the 90s and 00s toward interoperation support through application unification and/or characterisation.

This paper presents an overview of the standardisation efforts on interoperation addressing process interoperation through integration, unification and support of federated environments.

1.1 Interoperation

Interoperability is defined in the literature and in standardisation as:
Definition 1: ability of two or more systems or components to exchange information and to use the information that has been exchanged (IEEE, 1990)
Definition 2: achieved only if the interaction between two systems can, at least, take place at the three levels: data, resource and business process with the semantics defined in a business context (Chen, Doumeingts, 2003)
Definition 3 (for Computer Science): ability to exchange and use information (usually in a large heterogeneous network made up of several local area networks) (WordNet 2.1, 2005)

Figure 1 presents a summary of various information exchange and system features that are expected to be compatible for satisfactory information exchange between partners at different extents of compatibility.

Following the rather large R&D efforts in the US Air Force (IDEF) and the European Union (ESPRIT) in the 70s and 80s, the first SDO standard addressing the problem of interoperability of heterogeneous systems was ISO 14258 *Industrial automation systems – Concepts and rules for enterprise models* (ISO-WG1 Overview, 2007), where the rules apply in IT-based applications and processes as well.

The intention of the standard is to describe the enterprise in models and use those models to identify and resolve interoperability problems. Besides other sections, it identifies *Requirements for standards on model interoperability* and defines three ways in which models can be related to each other:

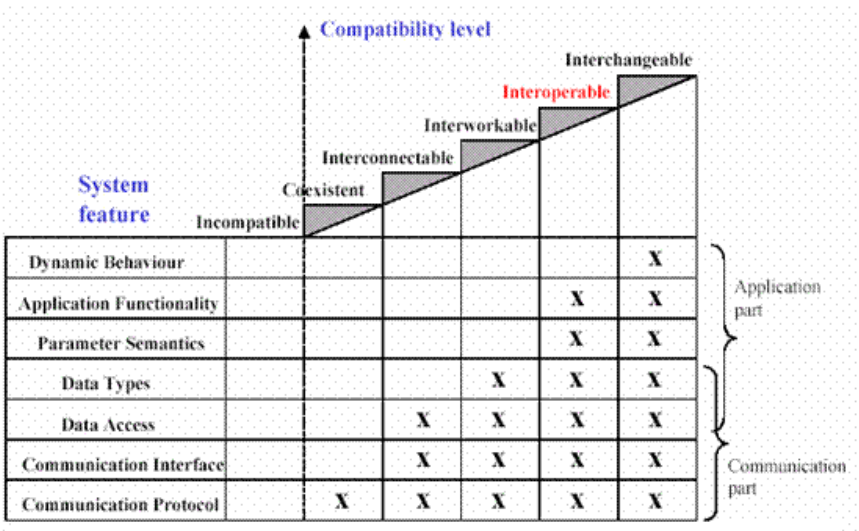

Figure 1: Information Exchange (IEC TC 65/290/DC, 2002)

- integrated (use of common modelling form),
- unified (use of common meta-level structure),
- federated (use of model characterisation to dynamically accommodate different models).

However, integration and unification are special cases, which can only be achieved in its true meaning for a limited time period only, due to the need for evolution - a property of any system in use. Therefore, the most important scenario for interoperation of enterprise models, processes, and applications is the federated situation.

All three approaches to interoperability need standards to support their realization. Depending on the situation, the elements to be defined in or required by a standard are different. To achieve integration or unification, the constructs for models are the elements that must be standardized either explicitly or through their meta-model. To achieve federation, the characteristics of the interfaces are the elements that must be standardized.

For each chosen element to be standardized, the standard must define:

- the form(s) in which the element is represented,
- the relationships between the element and other model elements,
- the attributes of the element, and
- the dynamics of associated interactions.

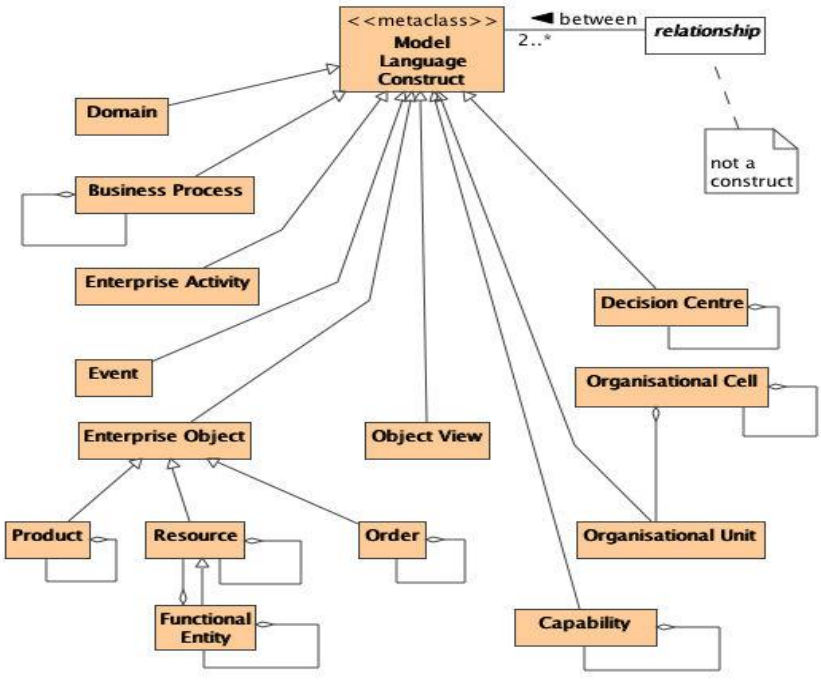

Figure 2: Language Constructs for Enterprise Modelling

2 Standards supporting Interoperation

The following four standards are intended to support interoperability among enterprises. Other standards providing guidance and general requirements for standard

developers and standard users are summarised in Figure 7 at the beginning of the next section.

2.1 CEN/ISO 19440 - Language Constructs for Enterprise Modelling (ISO-WG1 Overview, 2007)

defines a set of fourteen model language constructs for enterprise modelling (see Figure 2) together with their definitions and descriptions (templates). Functionality of an enterprise domain is described by processes consisting of activities requiring capabilities and supported by objects. The latter represent information and resources (Functional entities) providing capabilities. Organisational aspects are captured by organisational and decisional hierarchies. The standard also identifies their relationship to four basic model views (Function, Information, Resource, Organisation) allowing a reduction in model complexity during the modelling process.

The language is intended to model enterprise processes by representing both their structure and their dynamics while capturing the information necessary for model-based simulation leading to model-based process monitoring and control.

2.2 CEN/ISO 11354 NWI - Requirements for establishing manufacturing enterprise process interoperability[1] (ISO-WG1 Overview, 2007)

identifies requirements for interoperation both within and between enterprise systems. It defines an interoperability framework (see Figure 3) and specifies requirements for the underpinning process metadata that must be in place to establish solutions for various concerns of interoperability (business, processes, services, data). It describes the particular requirements for different kinds of environments (unified, integrated, and federated) and focuses on requirements that enable communication rather than requuirements that define the communication itself, thus remaining independent from specific technologies. The framework indicates the different extent to which interoperability may be achieved using various approaches. It also addresses barriers and potential solutions for selected enterprise situations.

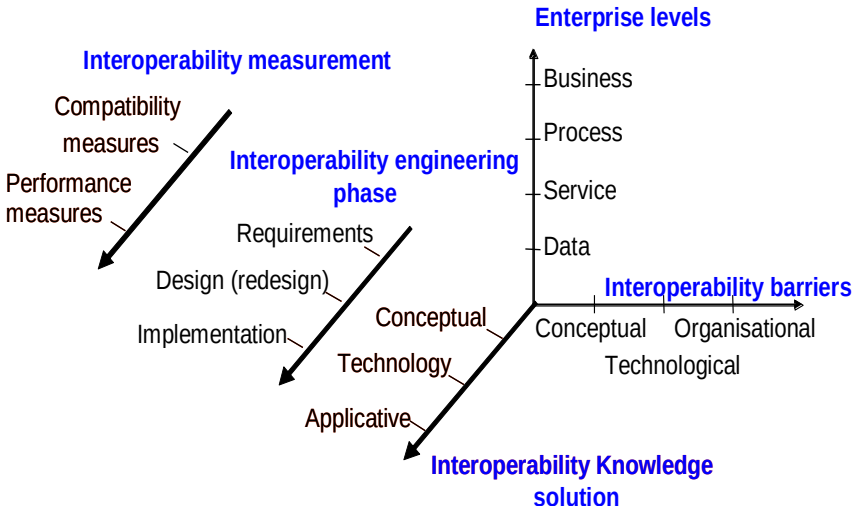

Figure 3: Interoperability Framework

2.3 ISO 15745 - Open systems application integration frameworks (ISO-WG1 Overview, 2007)

outlines an Application Integration Framework (AIF) as a set of elements and rules for describing application interoperability profiles (AIP) (see Figure 4).
The middle section of Figure 4 shows the AIP (which can contain one or more other AIPs) consisting of one process profile, one or more resource profiles, and one or more information exchange profiles. Underlying the AIP are the relevant integration models which represent the application requirements. With its focus on shop floor application Figure 4 shows the next level of details for the resource profile consisting of communication, device, human, material and equipment profiles. The standard represents in detail the most widely used shop floor communication technologies in the form of Device Profiles.

[1] new work item

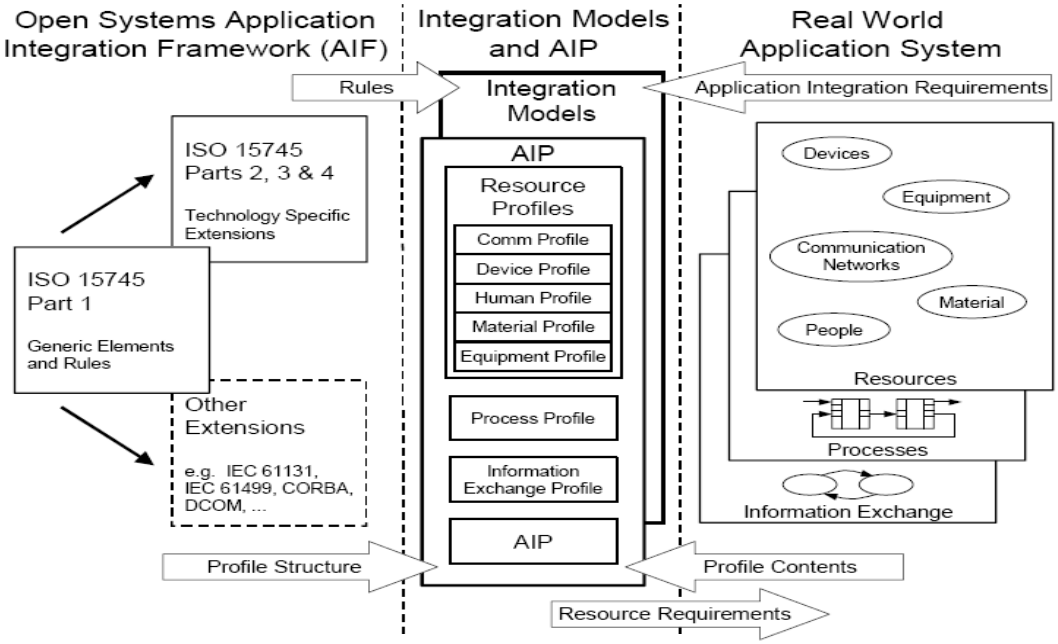

Figure 4: Context of ISO 15745

2.4 CEN/ISO 16100 - Manufacturing software capability profiling for interoperability[2] (ISO-WG1 Overview, 2007)

specifies a framework for assessing the interoperability of a set of software products used in the manufacturing domain. To facilitate integration into manufacturing applications a methodology for constructing profiles of manufacturing software capabilities and a set of requirements for interface services and protocols used to access and edit capability profiles are defined. Figure 5 shows the concepts defined in the different parts of ISO 16100.

Starting from the manufacturing software requirements, the analysis leads to the identification of a required software unit profile. Searching the database will lead to the identification of an available software package or a new one has to be provided. New profiles are tested and added to the database.

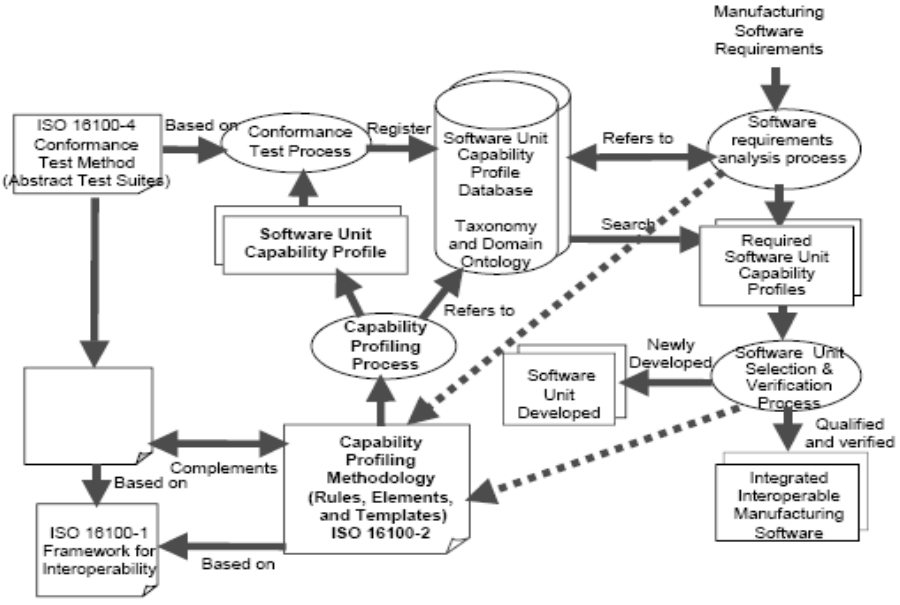

Figure 5: Concepts of Capability Profiles for Software Interoperability

[2] parts 5 & 6 still under development

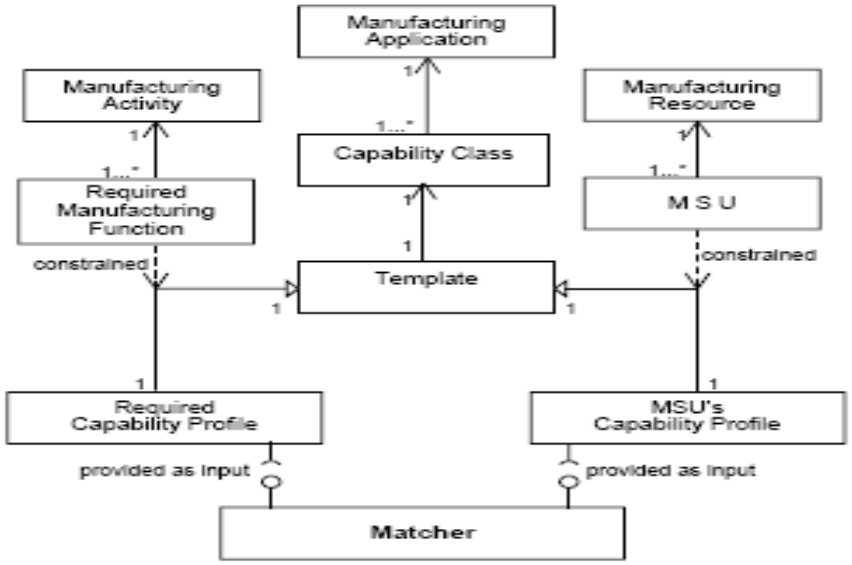

Figure 6: Matching of Capability Profiles

Figure 6 demonstrates the procedure for matching the capability profiles required by the manufacturing activity and provided by the manufacturing resource – the manufacturing software unit. The two profiles are compared and the degree and type of mismatch is analysed and evaluated. The common template is stored as the capability class of the particular manufacturing application.

3 Standards related to Interoperation – an Overview

In addition to the four standards intended for supporting aspects of interoperability described above, the following overview presents related standards for use by both standards developers and standards users (Figure 7). Structured into frameworks, languages and related standards, the overview shows standards developed by SDOs (ISO, CEN and IEC) and selected standards developed by industry consortia (OMG and OASIS). The four standards described above are indicated by the yellow colour (the new work item CEN/ISO 11354 has been included, but only partly fits the selected structure, only part 1 is on frameworks, whereas the followng pats will address integated, unified and federated approaches).
A short description of the ISO standards follows.

General Standards		
ISO/IEC 42010 Recommended Practice for Architectural Description of Software-Intensive Systems (IEEE 1471) **ISO 14258** Rules and Guidelines for Modelling **ISO 15704** Requirements for Enterprise Reference Architectures (Needs for Frameworks, Methodologies, Languages, Tools, Models, Modules) **ISO 27387** Reference for process modeling methods **OMG BPMN** Business Process Modelling Notation		
Frameworks	*Languages*	*Related Standards*
CEN/ISO 19439 Framework for Modelling	**CEN/ISO 19440** Constructs for Modelling	**ENV 13550** Model Execution Services (EMIES)
ISO 15745 Framework for Application Integration	**ISO 18629** Process Specification Language	**ISO 15531** Mfg. Management Data Exchange
ISO 15288 Life Cycle Management	**ISO/IEC 15414** ODP Enterprise Language	**ISO 16100** Mfg. Software Capability Profiling
CEN/ISO 11354 Mfg. Enterprise Process Interoperability	**OMG BPEL4WS** Business Process Execution Language	**ISO 18435** Diagnostics, capability assessment, and maintenance applications integration
ISO/IEC 10746 (ODP) Open Distributed Processing	**OASIS ebXML** e-Business using eXtensible Mark-up Language	
OMG MDA Model Driven Architecture		**IEC/ISO 62264** Control Systems Integration
	OMG UML Unified Modelling Language	**OMG BPDM** Business Process Definition Metamodel

Figure 7: Overview of related standards

3.1 General Standards

3.1.1 ISO/IEC 42010 Recommended Practice for Architectural Description of Software-Intensive Systems[3] (IEEE 1471) (JTC1/SC7/WG42) (ISO-WG1 Overview, 2007)
addresses the pre-requisites for the creation, analysis, and sustainment of software-intensive systems architectures, and the recording of such architectures in terms of *architectural descriptions*. A conceptual framework and term taxonomy for the architectural description of systems is established. Annexes provide the rationale for key concepts and terminology, the relationships to other standards, and examples of usage

3.1.2 ISO 14258 Concepts and Rules for Enterprise Models[4] (TC184 SC5/WG1) (ISO-WG1 Overview, 2007)
defines "the elements to use when producing an enterprise model, concepts for life-cycle phases, and how these models describe hierarchy, structure, and behaviour." Also contains guidelines and constraints for relating the real world to enterprise models through views. This latter concept is equivalent to the views of CEN/ISO 19439. As a result of a recent systematic review ballot, this standard is scheduled for withdrawal when a systematic review revision of ISO 15704 occurs.

3.1.3 ISO 15704 Requirements for enterprise-reference architectures and methodologies[5] (TC184 SC5/WG1) (ISO-WG1 Overview, 2007)
places the concepts used in methodologies and references architectures such as ARIS, CIMOSA, GRAI/GIM, IEM, PERA, and ENV 40 003 within an encompassing conceptual framework that allows the coverage and completeness of any such approach to be assessed. The IS draws heavily on the work of the IFAC/IFIP Task Force on Enterprise Integration and on previous work from Purdue University. The conceptual framework is textual and relatively informal. It does not provide a basis for actual implementations and requires understanding of the field to apply. An informative annex to this standard details the Generalized Enterprise Reference Architecture and Methodology (GERAM) prepared by the IFAC/IFIP Task Force. Amendment 1 adds informative annexes for an Economic View and a Decision View as alternative views of an enterprise model. A systematic review of ISO 15704 has initiated a revision project starting in 2007.

3.1.4 ISO 27387 System integration - Reference for process modeling methods: Part 1 Characterizing process modeling common concepts[6] (TC184 SC5/WG1) (ISO-WG1 Overview, 2007)
specifies those characteristics that a process model must exhibit in order to: assess manufacturing process efficiency, support process improvement, externalize process operational information relevant to process performance, and enhance comprehension and communication. It does not include descriptions of process composition or otherwise aggregate into larger frameworks or architectures. It is not a process characterization language but rather characterizes the range of processes so that suitable languages are developed to support process characterizations.

3.1.5 OMG Business Process Modelling Notation (BPMN) (OMG - Object Management Group), (OMG-1, 2007)
provides for interoperation of business processes at the human level establishing a Business Process Diagram (BPD), which is designed for use by the people who design and manage business processes. It also provides a formal mapping to an execution language of BPM Systems (BPEL4WS). Thus, BPMN provides a standard visualization mechanism for business processes defined in an execution optimized business process language.

3.2 Frameworks

3.2.1 CEN/ISO 19439 (CIM Systems Architecture – Framework for enterprise modeling TC310/WG1 TC184 SC5/WG1) (ISO-WG1 Overview, 2007)
specifies a framework of three dimensions (modeling phase for different life-cycle stages, generic concepts that are then specialized to an industry sector or industrial activity and then to a particular enterprise, and views that classify concepts by four areas of concern or modeler viewpoint) that serves as a common basis to identify and coordinate standards development for modeling enterprises, emphasizing, but not restricted to, computer integrated manufacturing. The standard serves as the basis for further standards for the development of models that will be computer-enactable and enable business process model-based decision support leading to model-based operation, monitoring and control.

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[3] currently reworked

[4] under revision

[5] under revision

[6] under development

*3.2.2 ISO 15745 Open systems application integration framework (TC184 SC5/WG5) (ISO-WG1 Overview, 2007)*defines elements and rules that facilitate – the systematic organization and representation of the application integration requirements using integration models; - the development of interface specifications in the form of application interoperability profiles (AIPs) that enable both selection of suitable resources and the documentation of the 'as built' application.

3.2.3 ISO/IEC 15288 Life Cycle Management – Life Cycle Processes (JTC1/SC77/WG7) (ISO-WG1 Overview, 2007)
establishes a common framework for describing a complete set of well-defined processes most commonly found during the life-cycle of a system and associated terminology. The processes may be applied throughout the life cycle for managing and performing the conception, development, production, utilization, support and retirement of systems. This is accomplished through the involvement of all interested parties with the ultimate goal of achieving customer satisfaction. The standard also provides for the definition, control and improvement of the life cycle processes used within an organization or a project. It concerns those systems that are man-made and are configured with one or more of the following: hardware, software and humans.

3.2.4 CEN/ISO 11354 Requirements for establishing enterprise interoperability in manufacturing-enterprise processes and their models (CEN TC310/WG1 TC184 SC5/WG1) (ISO-WG1 Overview, 2007)
identifies operational levels of enterprises for which interoperability needs are envisaged. It then identifies concerns (business, process, services, data) and barriers (conceptual, technology, organizational) to interoperability and specifies approaches (integrated, unified, federated) to overcome these barriers. Normative requirements for potential solutions to those barriers are presented in additional parts of this standard. The focus is on enabling the communication rather than defining the communication itself, and is thus independent of specific technologies. The standard draws heavily on work from the European projects ATHENA, INTEROP and others. This project and its various parts use the acronym MEPI (Manufacturing-Enterprise Process Interoperability)

3.2.5 ISO/IEC 10746 Open Distributed Architecture (ODP) (JTC1/SC21/WG7) (ISO/IEC 10746, 2007)
defines a framework for the specification of ODP systems comprising 1) five viewpoints, enterprise, information, computational, engineering and technology, which provide a basis for the specification of ODP systems; 2) a viewpoint language for each viewpoint, defining concepts and rules for specifying ODP systems from the corresponding viewpoint (see below for enterprise viewpoint).

3.2.6 OMG Model Driven Architecture (MDA) (OMG - Object Management Group) (OMG-2, 2007)
focuses primarily on the functionality and behaviour of a distributed application or system, not the technology in which it will be implemented. It divorces implementation details from business functions. Thus, it is not necessary to repeat the process of modelling an application or system's functionality and behaviour each time a new technology (e.g., XML/SOAP) comes along. Mapping to the supported MDA platforms will be implemented by tools, easing the task of supporting new or different technologies. OMG expanded its scope to include modelling with the adoption of the Unified Modelling Language (UML) (see below) and Meta-Object Facility (MOF).

3.3 Languages

3.3.1 CEN/ISO 19440 Constructs for enterprise modeling (CEN TC310/WG1 TC184 SC5/WG1) (ISO-WG1 Overview, 2007)
defines and describes the core constructs found within the enterprise dimensions of ISO 19439 (model phase, view, and genericity) that are necessary for computer-supported modeling of enterprises. It focuses on the computer integration of information aspects of manufacturing, including the management and control technology and the requisite human tasks. Models generated using constructs in accordance with that framework will be computer processable and ultimately enable the daily operations of an enterprise to be monitored and controlled by such models.

3.3.2 ISO 18629 Process specification language (TC184 SC4/5/JWG8) (ISO-WG1 Overview, 2007)
specifies a language for the representation of process information, which is a process specification language. It is composed of a lexicon, an ontology, and a grammar for process descriptions. It describes what elements inter-operable systems should encompass, but not how a specific application implements these elements.

3.3.3 ISO/IEC 15414 ODP Reference Model – Enterprise Viewpoint (JTC1/SC7/WG19) (ISO/IEC 15414, 2007)
defines a language of concepts, structures and rules for developing, representing and reasoning about a specification for an ODP system from the enterprise viewpoint. The rules establish correspondences between the language and other viewpoint languages (defined in ISO/IEC 10746-3) to ensure the overall consistency of the specification.

3.3.4 OASIS Web Services Business Process Execution Language (WS-BPEL) (OASIS - Organization for the Advancement of Structured Information Standards) (OASIS-1, 2007)
is a meta-language for the implementation of executable business processes or describing non-executable abstract processes of the business. BPEL4WS is a language for composing Web services from existing services using XML syntax and is now linked with BPMN.

3.3.5 OASIS e-Business using extensible Mark-up Language (eBXML) (OASIS - Organization for the Advancement of Structured Information Standards) (OASIS-2, 2007)
provides a framework in which EDI's substantial investments in Business Processes can be preserved in an architecture that exploits XML's new technical capabilities. The ebXML initiative is targeted at every sector of the business community, from international conglomerate to small and medium sized enterprises engaged in business-to-business and business-to-consumer trade.

3.3.6 OMG Unified Modelling Language (UML) (OMG - Object Management Group) (OMG-3, 2007)
helps to specify, visualize, and document models of software systems and non-software systems, including their structure and design. UML can be used to model just about any type of application, running on any type and combination of hardware, operating system, programming language, and network. Built upon fundamental OO concepts including *class* and *operation.* It is a natural fit for object-oriented languages, but it can used to model non-OO applications as well.

3.4 Related Standards

3.4.1 ENV 13550 Model Execution Services (EMEIS) (TC310/WG1) (ENV, 2007)
identifies the requirements for a basic set of functionalities needed in enterprise engineering for creating and using enterprise models. This set may be expanded in the course of technology evolution. It identifies so far as found possible those standards, services, protocols and interfaces which are necessary for the computer-based development and execution of enterprise models and model components that have been constructed in accordance with ENV 40003 (now CEN ISO 19439) and ENV 12204 (now CEN ISO 19440).

3.4.2 ISO 15531 Manufacturing Management Data Exchange (TC 184 SC4 WG8) (ISO SC4/WG8, 2007)
specifies the characteristics for a representation of manufacturing management information over the entire industrial process. It provides the necessary mechanisms and definitions to enable manufacturing management data to be shared and exchanged within the factory, with other plants or companies. The standard is mainly focused on discrete manufacturing but not limited to it.

3.4.3 ISO 16100 Manufacturing software capability profiling (TC 184 SC5/WG4) (ISO-WG1 Overview, 2007)
specifies a manufacturing information model that characterizes software-interfacing requirements, a framework for the interoperability of software products used in the manufacturing domain and facilitates its integration into a manufacturing application. This framework addresses information exchange models, software object models, interfaces, services, protocols, capability profiles, and conformance test methods.

3.4.4 ISO 18435 Diagnostics, capability assessment, and maintenance applications integration[7] (TC 184 SC5/WG7) (ISO SC5/WG7, 2007)
defines an integration modelling method and its use to integrate diagnostics, capability assesement, prognostics, and maintenance applications with production and control applications. It enables opportunities for improved supply chain collaboration and interoperability to support dynamic production requirements. It describes integration models and interfaces and identifies applications that can utilize these interfaces to improve interoperability.

3.4.5 ISO/IEC 62264 Enterprise-control system integration[8] (TC 184 SC4/5/JWG15) (ISO-WG1 Overview, 2007)
defines the interfaces between enterprise activities and control activities. This standard provides standard models and terminology for describing the interfaces between business systems of an enterprise and its manufacturing-oriented systems.

3.4.6 OMG Business Process Definition Metamodel (BPDM) (OMG - Object Management Group) (OMG-4, 2007)
provides the capability to represent and model business processes independent of notation or methodology, thus bringing these different approaches together into a cohesive capability by using a "meta model" – a

[7] under development

[8] parts 4 & 5 under development

model of how to describe business processes with well defined connections between terms and concepts. This meta model captures the meaning behind the notations and technologies in a way that can help integrate them and leverage existing assets and new designs. The meta model uses the OMG "Meta Object Facility" (MOF) standard to capture business processes in this very general way and to provide an XML syntax for storing and transferring business process models between tools and infrastructures.

3.5 General Support

3.5.1 ISO Study Group on Vocabulary[9] *(TC184 SC5/WG1) (ISO-WG1 Overview, 2007)*
collects terms used in SC5 standards and provides: a listing of defined terms together with the relevant public definitions, a proposed taxonomy and, guidance for terms use and definitions of new terms.

3.5.2 OMG Semantics of Business Vocabulary and Business Rules (SBVR) (OMG - Object Management Group) (OMG-5, 2007)
defines the semantics of business vocabulary, business facts, and business rules; as well as an XMI schema for the interchange of business vocabularies and business rules among organizations and between software tools.

4 Conclusions

The state of the art in standardisation for interoperation is still far from being sufficient to solve all the problems in ICT-based information exchange needed to suppport business cooperations and collaborations. Many standards exist for integration and unification of enterprise operations (e.g. CEN/ISO 19440 or OASIS ebXML), which may be adapted for cooperating and collaborating enterprises when sufficient preparation times are available. But for the more normal situation of heterogeneous ICT systems to interoperate on short notice only standards for partial support are available (ISO 15745 and ISO 16100).

A more general approach is followed in CEN/ISO 11354, which aims to define the interoperability domain, structure generic interoperability issues and identify potential solutions, either though integration, unification or by supporting federation. The latter is the most challenging task. A potential solution is the partial support provided by ISO 15745 and ISO 16100, both provide a priori knowledge of the exchanging entities by defining application profiles. These profiles identify the input/output capabilities of the applications and thereby ease their linking. The concepts described as Interoperability Service Unit (ISU) proposed in the European Enterprise Interoperability Research Roadmap (EIRR, 2006) will be considered as well

[9] under revision

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