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Enterprise modelling and architecture — Requirements for enterprise-referencing architectures and methodologies

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National foreword

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Modélisation et architecture d'entreprise — Exigences pour les architectures et les méthodologies de référencement d'entreprise

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 184, *Automation systems and integration*, Subcommittee SC 5, *Interoperability, integration, and architecture for enterprise systems and automation applications*.

This second edition cancels and replaces the first edition (ISO 15704:2000), which has been technically revised. It also incorporates the Amendment ISO 15704:2000/Amd.1:2005.

The main changes compared to the previous edition are as follows:

— alignment of terminology for consistency with other standards developed by ISO/TC 184/SC 5;

— incorporation of the rules and guidelines for modelling from ISO 14258 to express enterprise-referencing architecture methodologies;

— revision of content related to recursive structure and iterative methods;

— redrafting of life history concept to address enterprise change management;

— discussion of modelling dimensions necessary for user views, including the extent of detail and composite models that span dimensions;

— harmonization with ISO/IEC/IEEE 42010 and other International Standards related to architecture for enterprise systems;

— inclusion of discussion concerning the relationship of this document with other International Standards related to architecture for enterprise systems (ISO/IEC 10746, IEC 62264, ISO 15745);

— updating of Annex B on Generalized Enterprise Reference Architecture and Methodology (GERAM) in accordance with GERAM 1.6.3.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Introduction

0.1 Rationale for enterprise architectures and models

Industrial and information age enterprises create and modify manufacturing and business operations to improve performance in local and global markets. In operation they deploy a variety of resources including people, information systems, automated machinery and business services. Individually and collectively these resources provide the functional capabilities required to perform manufacturing and business processes and their constituent activities. The arrangement, targeting and interworking of resources need to accomplish the enterprise mission, which requires suitable business rules and organizational structures that enable the enterprise to provide products and services in conformance with agreed upon criteria.

Enterprises operate under uncertain and changing market and environmental conditions that make ongoing enterprise engineering beneficial. Enterprises cooperate within a heterogeneous environment with multiple constituents using different models and systems. In addition, most enterprises operate within the context of another enterprise with which it interoperates, as with a supply chain or the parent company. It follows that enterprise personnel have a variety of responsibilities in the conception and ongoing development of the mission, business rules, manufacturing and business processes, organizational structures, and supporting resources and services. Because of the complexity involved in enterprise engineering, invariably it becomes necessary to deploy means of assessing, structuring, coordinating and supporting these engineering activities, including means for collaboration support and interoperation.

Generalized enterprise-referencing architecture concerns and components of enterprise modelling constitute a reference base that provides a generally applicable means of arranging and coordinating enterprise engineering and associated technology development and deployment projects. By adopting and adapting such a reference base, enterprise personnel can cooperate in progressing enterprise engineering projects, improving the enterprise, improving stakeholder's communications and utilizing enterprise resources. By adopting appropriate tool sets, enterprise personnel can reuse in a practical way explicit enterprise designs and models to realize the benefits of enterprise engineering on a continual basis and realize further improvements in enterprise operation.

Such a reference base needs to include capabilities that:

— capture concerns of mission fulfilment stakeholders (manufacturing, transport, service delivery, etc.) and of business stakeholders;

— describe suitable solutions to identified problems within the enterprise;

— model the whole life history of an enterprise integration project from its initial concept through development, operation and finally decommissioning or obsolescence; and

— encompass the people, processes, resources and organizations involved in performing, managing, and controlling the enterprise mission.

From an enterprise engineering perspective, the following distinction is drawn:

— enterprise architecture refers to the arrangement of physical components, logical relationships, and human interactions involved in the development, implementation and operation for a programme such as enterprise integration or other enterprise related programme, usually including a set of projects; and

— system architecture refers to the arrangement of physical components and logical relations of a system that is a constituent of an enterprise; for example, the computer-control-system part of an overall enterprise or product.

This document does not present or adopt specific methodologies for creating or using enterprise architectures or models. The focus is on establishing a reference base capable of supporting specific enterprise programmes, rather than a design intended to fulfil the stated requirements.

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This document identifies an extensive collection of potential artefacts for expressing an enterprise-referencing architecture and its associated methodologies. Not all of these artefacts will be applicable, necessary or even desirable for all architecting efforts. The identification of these artefacts assures that this document meets the needs of the widest possible number of enterprise-referencing architecture and methodology situations. Users of this document need to assess not only the value of generating an identified artefact but also the value of maintaining that artefact under the changing circumstances of the referenced enterprise.

0.2 Rationale for this document

Well-designed standards in the domain of enterprise integration and modelling provide a point of reference for enterprise architects and designers, thereby significantly reducing the risk of investing in islands of integration. Where an island does exist, these standards assist the architect or designer to create the translation necessary for the island to interact within an established context. A standard for enterprise-referencing models enhances interoperability by establishing the elements that are required in a model intended to support enterprise architecture.

This document defines concepts, rules and requirements for architecture descriptions that refer to an enterprise, most often articulated as models, with the intent to guide and constrain other standards or implementations that do or will exist on the topic. To realize this intent, this document specifies the concepts to use when producing an enterprise-referencing architecture (see Clause 5) and when constructing enterprise-referencing models (see Clause 6). This document provides a reference base, guidelines and constraints for enterprise architecture and models to anyone engaged in enterprise activities where models are utilized.

0.3 Benefits of this document

The requirements of the reference base for enterprise-referencing architecture and models in this document allow assessment of an enterprise architecture framework or other approach as well as associated methodology and languages for completeness with respect to current and future purpose of the architecture effort. This document will help guide development programmes.

When conforming implementation designs have the same technology areas and nomenclature, or can map to them readily, the information from one enterprise or process is more readily sharable with information of another enterprise or process.

The benefit will be most relevant to any group charged with improving an enterprise infrastructure or its processes. Such a group will find it necessary to either select or create a reference architecture of its own with terminology that pertains specifically to the company, industry, and culture involved. This document will help guide that selection or creation.

This document expects users that are:

— enterprise planners, builders, modifiers, and analysts using the requirements to check completeness of their activity;

— enterprise-referencing model builders using the requirements to assure consistency between models to enable model interoperability; and

— developers of standards for enterprise representation using the requirements to assure consistency between their standards and this document.

NOTE While the requirements specified herein cover a broad range of enterprise considerations, many users find it advantageous to structure the topics considered into a specific framework for their own work. Such a framework is a methodological choice of the user and goes beyond the scope of this document. Annex B discusses a framework consistent with this document and other International Standards provide further framework guidance.

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Enterprise modelling and architecture — Requirements for enterprise-referencing architectures and methodologies

1 Scope

This document specifies a reference base of concepts and principles for enterprise architectures that enable enterprise development, enterprise integration, enterprise interoperability, human understanding and computer processing. This document further specifies requirements for models and languages created for expressing such enterprise architectures.

This document specifies those terms, concepts and principles considered necessary to address stakeholder concerns and to carry out enterprise creation programmes as well as any incremental change projects required by the enterprise throughout the whole life of the enterprise. This document forms the basis by which enterprise architecture and modelling standards can be developed or aligned.

This document does not define standard enterprises, standard organizational structures, standard enterprise processes, or standard enterprise data. In addition, this standard does not specify enterprise modelling processes.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
architecture
conceptualization of the form, function, and fitness-for-purpose of an *enterprise* (3.4) in its *environment* (3.9), as embodied in the elements of the enterprise, the relationships between those elements, the relationship of the enterprise to its environment and the principles guiding the design and evolution of the enterprise

Note 1 to entry: Since architecture in an enterprise context, e.g. an enterprise architecture, is always conceptual, the expression of architecture as an architecture description is through models of the enterprise reality to which the architecture applies. Detailed designs conforming to an enterprise architecture description often take less abstract forms as they approach enterprise reality.

Note 2 to entry: The notion of fitness-for-purpose distinguishes architecture from other characteristics of design by adding the obligation of elegance in efficiency and effectiveness to design form and function — a distinguishing characteristic separating an ad hoc assemblage of parts necessary to conduct an enterprise from an intentional composition of constituent elements necessary to achieve and sustain superior enterprise performance.

[SOURCE: ISO/IEC/IEEE 42010:2011, 3.2, modified — Content of original definition has been adapted to the context of this document and Notes to entry have been added.]

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3.2
aspect
distinguishing characteristic, manifest by content projection from an integrating *enterprise model* (3.6)

Note 1 to entry: In this document the term aspect usually refers to a collection of concerns that are better addressed by looking across various *views* (3.23), i.e. concerns best addressed by a view across other model views. The scale and scope of these kinds of broad-based concern collections are poorly handled by a single model representation but can be effectively rendered by selecting a composite view from existing model view content.

3.3
business process
partially ordered, often nested, set of *enterprise* (3.4) activities that can be executed to achieve some desired result in pursuit of a specified objective of an enterprise or a part of an enterprise

3.4
enterprise
human undertaking or venture that has explicit and clearly defined *mission* (3.13), goals, and objectives to offer products or services, or to achieve a desired project outcome or business outcome

Note 1 to entry: When in operation, an enterprise functions as a system that realizes the mission through life cycle activities within a life history.

Note 2 to entry: In this document, "enterprise" refers to concrete (e.g. company, project or extended supply chain enterprise) or abstract (e.g. virtual enterprise) entities.

Note 3 to entry: One or more organizational unit participates in an enterprise. For an enterprise involving more than one such unit, each brings various *resources* (3.21) forward for use, participating to the extent that it benefits from their involvement, which most often occurs to address some challenge that it is unable to address on its own.

3.5
enterprise engineering
discipline applied in carrying out any efforts to establish, modify, or reorganize any *enterprise* (3.4)

Note 1 to entry: An enterprise engineering and architecting methodology provides guidance for efforts to establish, modify, validate or reorganize an enterprise.

3.6
enterprise model
representation of an *enterprise* (3.4) as well as entities within an enterprise, their interrelationships, their decomposition and detailing to the extent necessary to convey what the enterprise intends to accomplish and how it operates

Note 1 to entry: An enterprise model, which is used to improve the effectiveness and efficiency of the enterprise, identifies and specifies essential components and elements to any necessary extent of detail, including any subsystems and constituent models of the enterprise, e.g. an enterprise *architecture* (3.1) model.

[SOURCE: ISO 19439:2006, 3.23, modified — The words "abstraction of an enterprise domain that represents enterprise entities" have been replaced with "representation of an enterprise as well as entities within an enterprise", the words "what it intends" have been replaced with "what the enterprise intends", and Note 1 to entry has been added.]

3.7
enterprise-referencing
applicable to an *entity* (3.8) that is, or includes, or is part of an *enterprise* (3.4)

Note 1 to entry: A generic enterprise *architecture* (3.1), an architecture for a specific enterprise, and an architecture that includes an enterprise as one of its elements are all enterprise-referencing architectures.

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3.8
entity
concrete or abstract thing in the domain under consideration

[SOURCE: ISO 19439:2006, 3.29]

3.9
environment
context that determines the setting and circumstances of technological, business, operational, organizational, political, regulatory, social, and other critical influences and constraints upon an *enterprise* (3.4), which affect or are affected by its development and behaviour, but are not controllable by the enterprise itself

Note 1 to entry: In the case of a nested enterprise, its environment may be within the larger enterprise.

[SOURCE: ISO/IEC/IEEE 42010:2011, 3.8, modified — Content of original definition has been adapted to the context of this document, incorporating content from ISO 19439:2006, 3.30, and Note to entry has been added.]

3.10
framework
structure expressed in diagrams, text and formal rules which relates the elements of an *enterprise* (3.4) *architecture* (3.1) to each other

Note 1 to entry: The purpose of a framework is to guide creation of one or more enterprise architecture descriptions.

[SOURCE: ISO 19439:2006, 3.31, modified — The words "the components of a conceptual entity" have been replaced with "the elements of an enterprise architecture", and Note 1 to entry has been added.]

3.11
genericity
extent to which a concept generalizes entities in a category or group

3.12
life cycle
set of distinguishable phases and steps within phases which an *entity* (3.8) goes through from its creation until it ceases to exist

Note 1 to entry: The phases of a nested *enterprise* (3.4) can be steps within the life cycle of the containing enterprise.

[SOURCE: ISO 19439:2006, 3.42, modified — Note 1 to entry has been added.]

3.13
life history
actual, recorded and configuration managed sequence of phases and steps within phases that an *entity* (3.8) goes through during its lifetime

3.14
mission
characterization of the effect that an *enterprise* (3.4) expects to achieve through the fulfilment of functional requests for products or services

3.15
model
representation of certain entities and their characteristics either (a) using a formalism, or (b) using an established or ad hoc modelling paradigm, approach, or technique

Note 1 to entry: An ad hoc model is more difficult to implement using an established design technique.

Note 2 to entry: A model may be a subset of a broader model.

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3.16
model-based
represented using a formalism which has a formal syntax and semantics, usually with a theoretical basis, and expressible in a symbolic language

Note 1 to entry: Presentation of such models is often graphical but the definition mandates that the graphical representation be translatable into a symbolic language, thereby constraining interpretation of the graphical representation.

Note 2 to entry: In order to satisfy specific *stakeholder* (3.22) concerns, "model-based" is often used as a qualifier to characterize a kind of design, or practice, e.g. model-based system engineering, model-based design, model-based specification.

3.17
modelling dimension
conceptual collection of *enterprise* (3.4) *entity* (3.8) *viewpoints* (3.24) related by kinds of architectural concerns and exhibiting reasonably distinct aggregating coordinates along a continuum

Note 1 to entry: Common modelling dimensions are life cycle, viewpoint, and *genericity* (3.11).

3.18
organization
distribution of responsibilities and authorities in the *enterprise* (3.4)

Note 1 to entry: Within an organization, people are often given role titles designating collections of responsibilities and authorities with roles arranged in an accountability hierarchy.

3.19
perspective
orientation of a *stakeholder* (3.22) or *model* (3.15) user relative to an identified domain

Note 1 to entry: A stakeholder's orientation can be formed by stakeholder concerns, as well as by their training, experience, cultural background, and their motivations.

3.20
reference base
source of information comprising descriptions of generalized *enterprise* (3.4) *architecture* (3.1) concepts, requirements and recommendations

3.21
resource
entity (3.8) that provides some or all of the capabilities required to execute an *enterprise* (3.4) activity

Note 1 to entry: In this document, resource is used in the system theory sense of entities that provide capabilities required by the system and are an essential part of the system itself. The resource description includes the identification and description of consumables (such as energy, air, coolant) that are required to be present in sufficient quantities to operate the resource. In contrast, material is reserved for process inputs that are required by the various activities such as raw materials, parts and assemblies.

Note 2 to entry: In this document, the term "resource" applies to non-human entities involved in enterprise entity operation. The involvement of humans is described by roles they carry out in the enterprise entity operation.

[SOURCE: ISO 19439:2006, 3.60, modified — The word "enterprise" has been deleted at the start of the definition, the last sentence of Note 1 to entry has been removed, and Note 2 to entry has been added.]

3.22
stakeholder
individual, team, organizational unit, or class thereof, having concerns relative to their *perspective* (3.19) about an *enterprise* (3.4), or its *architecture* (3.1), or in an architecture *entity* (3.8) of the enterprise

Note 1 to entry: Typical enterprise stakeholders include enterprise owners, enterprise customers, and enterprise employees responsible for receiving or delivering either products or services, and those persons or *organizations* (3.18) partnering with the enterprise to achieve its mission.

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Note 2 to entry: Enterprise architects are stakeholders of the enterprise architecture, but not necessarily stakeholders of the enterprise itself. A user of enterprise architecture or related models is an enterprise stakeholder. There can be observers of an enterprise that are not stakeholders for that enterprise.

[SOURCE: ISO/IEC/IEEE 42010:2011, 3.10, modified — Content of original definition has been adapted to the context of this document and Notes to entry have been added.]

3.23
view
work product expressing a selective perception or representation of a *model* (3.15), which emphasizes some specific feature or characteristic and disregards others

[SOURCE: ISO 19439:2006, 3.25, modified — Content of original definition has been adapted to the context of this document.]

3.24
viewpoint
identification of one or more kind of *model* (3.15) useful for addressing a collection of related *stakeholder* (3.22) concerns

Note 1 to entry: When the term viewpoint is used without any qualifier it refers to the general case. When the term viewpoint is used with a qualifier, the viewpoint applies to a specific collection of concerns, e.g. operational viewpoint, capability viewpoint, services viewpoint.

Note 2 to entry: A viewpoint identifies one or more models necessary and sufficient for expressing one or more *enterprise model* (3.6) *views* (3.23) that address the specific collection of related stakeholder concerns.

4 Abbreviated terms

CIM	Computer Integrated Manufacturing
CIMOSA	Computer Integrated Manufacturing Open Systems Architecture
EA	Enterprise Architecture
EAET	Enterprise Architecture and Engineering Tool
EAM	Enterprise Architecting, Engineering and integration Methodology
EI/EA	Enterprise Integration/Enterprise Architecture
EMEIS	Enterprise Model Execution and Integration Services
EML	Enterprise Modelling Language
EMO	Enterprise Module
EM	Enterprise Model
EOS	Enterprise Operational System
FIRO	Function, Information, Resource and Organization
GEM	GRAI Evolution Method
GEMC	Generic Enterprise Modelling Concept
GERA	Generalized Enterprise Reference Architecture
GERAM	Generalized Enterprise Reference Architecture and Methodology

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GIM	GRAI Integrated Methodology
GRAI	Graphs with Results and Actions Inter-related
IT	Information Technology
ODP	Open Distributed Systems
OMG	Object Management Group
PEM	Partial Enterprise Model

5 Requirements for enterprise-referencing architectures and models

5.1 General requirements

The requirements for enterprise-referencing architectures and models are cast as a framework relying upon the key principles of enterprise integration and interoperation found in Annex A.

The framework comprises the requirements for enterprise-referencing architectures in Clause 5 and models with modelling languages and associated methodologies in Clause 6. These architecture and model requirements assist with planning enterprise integration and interoperation by an individual or team, which determines and develops a course of action that is complete, accurate, and properly oriented to future business developments and economy of resources. The planners shall establish the following objectives among other potential objectives:

a) identify enterprise boundaries and relevant relationships to the environment in which it operates;

b) define present and possible future enterprise objectives;

c) describe significant tasks to perform;

d) identify the necessary kinds and quantity of information;

e) identify relevant enterprise elements and their relationships to enterprise objectives;

f) specify relationships among humans, processes, and equipment for the interoperation considered;

g) specify sufficient management functions and responsibilities;

h) identify relevant economic, cultural, and technological factors;

i) describe the extent of automation-support required;

j) provide modelling that can trace the whole life history of an enterprise entity including entity and relationship evolution;

k) describe decision-making structures and means for detecting inconsistencies;

l) maintain both human readable and machine processable forms of expression;

m) measure sufficiency and efficiency of enterprise architecting methodology as the extent to which the enterprise achieves objectives.

Enterprise-referencing architectures and models can address the role of humans, the description of processes, the identification of information, their relationships, and the representation of all supporting technologies throughout the life cycle of the enterprise.

Effort applied to the development of architectures, models and views needs to remain cognizant of the intended objectives and benefits to the enterprise, and to balance the effort required to achieve these outcomes. Typically, effort will be constrained by cost and/or schedule.

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5.2 Applicability and coverage of enterprise architecture

5.2.1 Kinds of enterprise

Enterprise-referencing architectures and the models that represent those architectures should be suitable for supporting the engineering of manufacturing and business enterprises of many conceivable sizes or varieties. Supported enterprise entities may be independent enterprises, e.g. companies, or parts of an enterprise, e.g. divisions, departments, or the business of collaborating and cooperating enterprises, e.g. supply chains, virtual enterprises, or even the enterprise operational systems or products. Reference architectures may exist for specific enterprises or systems, e.g. discrete parts manufacturing, process industries, complex system of systems interactions and behaviours, and information systems. The breadth and depth of the domain covered by an enterprise-referencing architecture and its representational models shall be identified clearly.

5.2.2 Characterizing enterprise architecture

A distinguishing characteristic of enterprise architecture arises because of the nature of enterprise creation and the purpose of the architecture relative to that enterprise. One kind of architecture — system architecture — relates to the design of a system, e.g., the computer control system part of an overall enterprise integration project. Another kind of architecture — enterprise architecture — involves the design of the enterprise that produces that system architecture. Enterprise architecture enables the creation of the system architecture by structuring the development and implementation of a project such as an enterprise integration or other enterprise development programme, which includes the creation of architecture descriptions in support of enterprise products or services.

Any elaboration or derivative of this document as a reference base for enterprise-referencing architecture and models shall be applicable for each enterprise entity within a specified domain.

The concrete form of an enterprise architecture conceptualization shall be as an architecture description, such description being suitable to the purpose for which the conceptualization occurs.

NOTE 1 In this document, the appearance of the term “architecture” often means its concrete form as an architecture description.

NOTE 2 Often one enterprise architecture supports the development and implementation of another enterprise, which produces its own enterprise architecture in support of the development and implementation of a product or service. See Annex B for more discussion of enterprise and architecture kinds and relationships among enterprise architectures.

5.2.3 Enterprise engineering and architecting methodology

A methodology, using this document or an elaboration or derivative of this document as a reference base, shall provide the necessary guidelines and management techniques for the identification of projects or programmes that support the deployment of an enterprise entity. Such a methodology can be model-based. While the enterprise engineering process can result in a specific enterprise model, the methodology shall be suitable for expressing concepts as described in 5.3 and components as described in Clause 6.

Such methodologies shall guide the user in the process of change management and provide methods of progression for every kind of life cycle activity for any enterprise entity within the scope of the reference base. These methodologies shall describe the process of enterprise integration and enterprise modelling that may include conceiving, defining, expressing, documenting, communicating, certifying proper implementation of, maintaining and improving the architecture of an enterprise. Different methodologies can exist to accommodate different characteristics of the enterprise change processes, whether complete integration processes, or incremental changes as experienced in a continuous improvement process.

NOTE Enterprise architectures and models need not rely upon a specific methodology and its accompanying framework. Potentially, many different methodologies and/or frameworks are possible to achieve the desired outcome. The primary consideration is applicability and suitability in relation to these requirements.

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5.2.4 Enterprise design

Enterprise architectures and models shall identify the information and activities necessary for managing, conceiving/defining, describing, designing, implementing, operating, maintaining, decommissioning, and disposing of an enterprise, and shall arrange enterprise activities in a form, e.g. a model, that allows a determination of their dynamic behaviour. Enterprise engineering uses the identified elements and interactions to describe in both human and machine-readable form the structure and behaviour of the enterprise.

5.2.5 Enterprise operation

Enterprise architectures and models shall identify the activities necessary for using the results of enterprise engineering in the operation itself. Such use may include model-based decision support and model-driven operation monitoring and control.

5.3 Essential concepts for enterprise-referencing architecture

5.3.1 Span of conceptual orientation

Various enterprise architecture property concepts are necessary to address the range of concerns expressed by stakeholders. Conceptual orientations express requirements for these properties.

Enterprise-referencing architecture concepts shall support enterprise engineering, operation of business processes, facility layout models, information system models, communication system models, logistics models, and models of enterprise resources, e.g. information technology, manufacturing technology, office automation.

5.3.2 Human oriented

Enterprise architectures and models shall identify and provide the means to represent human participation, such as organizational and operational roles, capabilities, skills, know-how, competencies, responsibilities, accountabilities, authorization, and relationships to the organization.

5.3.3 Process oriented

Enterprise architectures and models shall identify and provide the means to represent the enterprise operation. Such representations shall cover the behaviour of the operation including functionality, data flow among functions, and sequencing of control. The representations shall recognize the life cycle (5.3.9.1) and life-history (5.3.9.2) concepts and shall support process-oriented operations.

5.3.4 Interoperation oriented

Enterprise architecture and models shall identify and provide the means to represent collaborations and exchanges of entities, both information and physical, with external organizations in the enterprise environment.

5.3.5 Decision oriented

Enterprise architectures and models shall identify and provide the means to represent enterprise decision-making including the decision system structure, decision centres and decision processes.

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5.3.6 Realization oriented

5.3.6.1 Mission-fulfilment oriented

Enterprise architectures and models shall identify and provide the means to represent any process, and its constituent activities, involved in realizing the established mission of the enterprise in terms of providing enterprise products and services to its customers.

5.3.6.2 Mission-control oriented

Enterprise architectures and models shall identify and provide the means to represent any process, and its constituent activities, for accomplishing management and control in support of the mission of the enterprise according to the criteria established by enterprise management.

5.3.6.3 Economic oriented

Enterprise architectures and models shall identify and provide the means to represent economic characteristics of the enterprise through means to estimate and calculate the economic parameters of enterprise operation.

5.3.7 Technology oriented

Enterprise architectures and models shall identify and provide the means to represent all technologies employed in the enterprise operation.

5.3.8 Environment oriented

Enterprise architectures and models shall identify and provide the means to represent all concerns related to the interaction between the enterprise and its economic, social/political, and ecological environment, including concerns relating to the impact of creation, operation, transformation and decommissioning of the enterprise or of its constituent parts.

5.3.9 Lifetime oriented

5.3.9.1 Life cycle oriented

Enterprise architectures and models shall identify and represent the life cycle phases that are pertinent during the life of any enterprise. Different life cycle phases may have different models and different models may exist at an individual modelling phase. Where determined necessary, these models shall have the capability to interoperate and communicate with each other.

Life cycle phases shall encompass all activities from inception to decommissioning at the end of life of the enterprise. The characterization of life cycle phases shall be with respect to mutual dependencies and similarity of model content rather than a presumed chronological sequence. Life cycle phases may be concurrent, repeated, or empty as the enterprise modelling situation necessitates.

NOTE 1 If a phase is decomposed, different subsets can have different dependencies and therefore scheduled with more flexibly. This is particularly evident with software, where decomposition, to facilitate modularity, is a desired practice.

NOTE 2 Feeding model information forward and backward in life cycle activities enables value added iteration of enterprise processes that improves product quality. A phase can modify or extend the model of the previous phase according to the evolving needs of the following phase.

NOTE 3 Other standards, particularly those aligned with ISO/IEC/IEEE 15288, use the term stage rather than phase for a similar concept related to the development of a system. To maintain the distinctions between system architecture and enterprise architecture, this document adopts the term phase to characterize segmentation of activities during the lifetime of an enterprise.

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5.3.9.2 Life history oriented

The life history shall express the chronology of life cycle phase activities as they occur during the life span of the enterprise. Enterprise architectures shall specify methodologies capable of representing the life history of any enterprise; that is, the representation in time of activities carried out by the enterprise.

5.3.9.3 Complementary role of life cycle and life history

Using the life-oriented concepts of 5.3.9.1 and 5.3.9.2, the architect identifies enterprise activities within a life cycle phase, while life history allows the architect or user of the architecture to identify the corresponding time period in which the instances of these activities occur. This dual orientation accommodates the iterative nature of the life cycle activity dependencies while maintaining the time sequence of life history. These activity phase iterations identify different change processes required on the operational processes and/or the product development or customer services. See Figure B.3 for an illustrative example.

NOTE 1 Common acquisition practice mandates delivery milestones that strictly sequence the execution of life cycle phases chronologically such that the life history throughout acquisition mirrors completion of life cycle phase deliverables (e.g. the waterfall approach). However, the actual practice of enterprise architecting often necessitates a revisiting of specific phase activities to accommodate revisions and change orders (e.g. the spiral approach and the agile approach), thus life history chronicles the occurrence of all activity iterations as they actually occur in time, while allowing the overall deliverable milestones to remain as selected views of life history.

NOTE 2 Other standards, particularly those aligned with ISO/IEC/IEEE 15288, use the term life cycle stage instead of life history stage.

5.3.10 Stakeholder oriented

The enterprise architecture shall identify all stakeholders for that enterprise and their individual interests or concerns with respect to their perspective regarding the enterprise. Stakeholders and their perspectives can change during the life-history of the enterprise, therefore the iterative performance of life cycle phases can need to address changed stakeholder concerns.

Each enterprise stakeholder perspective shall have one or more concerns related to various characteristics of the enterprise life cycle and any individual concern can be shared by more than one stakeholder's perspective. The enterprise architecture description shall identify the explicit relationship between stakeholders, perspectives and concerns.

The expression of a stakeholder perspective concern relative to the enterprise shall be in terms consistent with those commonly used within the enterprise. Since enterprise concerns are the drivers for enterprise architectures and models, enterprise architectures and models shall clearly identify those enterprise concerns that are captured by reference.

5.3.11 Viewpoint oriented

An enterprise architecture shall provide a means for capturing and expressing collections of concerns, originating from stakeholder perspectives, as viewpoints from which views of the enterprise are made manifest during its lifetime. An enterprise viewpoint should establish the conventions for creating, depicting, interpreting, and analysing one or more model views of the enterprise associated with the viewpoint. Viewpoint conventions shall include the languages, notations, and kind of model for expressing the associated views, and any modelling methods, techniques for analysing, or other operations for the construction of the view.

An enterprise architecture description may use one or more viewpoints. Each viewpoint provides a collective framing of enterprise related concerns expressed from the perspective of stakeholders.

Enterprise architectures and models shall specify a set of viewpoints sufficient for spanning the expressed concerns of relevant stakeholder perspectives.

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A viewpoint within an enterprise architecture may specify more than one kind of model, e.g. an information model, a process model, a simulation model, perhaps by application at different life cycle phases. The application of such a viewpoint to the content of those models results in a view from each model consistent with the viewpoint. In some situations, the several views resulting from the application of a single viewpoint need to be composed into a more meaningful representation for stakeholders (see 5.3.13 and B.3.1.5.3).

A viewpoint can result in more than one architecture view, again perhaps one for each kind of model at each life cycle phase. Each view shall be associated with only one instance of the viewpoint's application, i.e. each application produces only one view instance, but there may be many views resulting from repeated instantiation of views by application of that one viewpoint. Similarly, each selection of a parameter value for a parameterized viewpoint may yield only one architecture view for each parameter selection, although that view can have different expression over the lifetime of the enterprise entity.

The enterprise view resulting from a viewpoint shall span the enterprise relative to the concerns that the view captures and expresses.

NOTE A viewpoint is a point of reference for the specification of corresponding views and all views have a corresponding viewpoint that governs view generation.

5.3.12 Model oriented

5.3.12.1 Representing enterprise architecture

Models of enterprise architecture have an abstract quality making the isolation of non-architectural enterprise models difficult. Architecture models, as representations of physical or conceptual entities, should not articulate those characteristics that do not contribute to the success of the enterprise mission.

In addition, since one enterprise may consist of several other enterprise entities (see 6.3.8), part of an enterprise model for one enterprise may be an enterprise architecture model for another enterprise. Therefore, as a reference base, this document considers all models with an enterprise scope as potentially pertinent to enterprise architecture. Clause 6 presents requirements, recommendations, and options for models typically found in architectural representations of an enterprise.

Following the requirements found in ISO/IEC/IEEE 42010, enterprise architecture models shall relate to one or more architecture viewpoints and its associated stakeholder's architectural concerns.

NOTE In the course of enterprise development some enterprise architecture models can transition into enterprise operational models or model-based executable enterprise processes, thus firmly binding the architecture of the enterprise to its operations.

5.3.12.2 Model-based engineering

Model-based enterprise architectures shall identify and provide the means to model an enterprise within the abstract space defined by conceptual modelling dimensions appropriate for the purpose of the architecture. The model-based formalism as applied to a particular model view shall align with one or more modelling dimensions of the enterprise and the same formalism can be useful for more than one dimension.

NOTE See Warfield and Christakis discussion about understanding dimensions[70].

5.3.12.3 Genericity

Model-based enterprise architectures shall provide the capability for representing generic enterprise elements (6.4.1), partial enterprise models (6.4.2), and particular enterprise models (6.4.3).

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5.3.12.4 Model integration

If an enterprise-referencing architecture takes the form of more than one model, then either these models shall be integrated or mechanisms shall be created to maintain their mutual consistency.

5.3.13 Model view oriented

5.3.13.1 Models and views

Enterprise architectures and models shall represent concepts that allow a description of an enterprise as an integrated model, presenting different aspects of concerns to the user as model views. Views should contain a subset of the content of the integrated model in order to concentrate on relevant concerns or aspects as specified in the governing viewpoint. The content of a model may be a model fragment, i.e. subset of the model, or specified portions of an instantiated model.

Different views may highlight certain aspects of an integrated model and hide other aspects. Model views are an important means for verifying stakeholder concerns for completeness, consistency, and integrability of enterprise models. As a projection of model content, views are the model medium used by humans to understand the enterprise.

The concept of view shall be applicable to models for any kind of enterprise across their entire life cycle.

NOTE Implicit in this notion of modelling view is an integrated model from which facts are taken. However, also possible for view projection is a federated model set consistent with a governing viewpoint. If the constituent models provide the necessary linkage between models or model segments, then a satisfactory model view is achievable.

5.3.13.2 Primary aspect for views

Two aspects are of primary importance in order to understand the enterprise: its structure and its behaviour throughout its life cycle. For this document, an information view shall represent the structural aspect of the enterprise as distinct from its resource and organization arrangements, and a function view shall represent the behavioural aspects of the enterprise arising from the structural connections within the enterprise as identified in that information view.

The information aspect is an orderly structured compilation, description, and representation of enterprise information. This information aspect describes the enterprise elements, their structure, relationships, the information to be supplied for function execution, and information describing function results. A physical model may represent portions of an enterprise that take a physical form as a construction from descriptive information, e.g. a scale model built from a blueprint.

The function aspect is a description and representation of activities and processes in the enterprise. This function aspect describes the processing of elements and the concatenation of single processing steps to process chains, reflecting their logical connection and interdependence. The function aspect emphasizes the representation of system behaviour, mutual dependencies, and influences of elements during function execution in the enterprise.

This document does not address the following:

— the manner in which the model expresses the content of these views;

— which content these views should include or not include;

— the necessity of other basic views, e.g. resource view, organization view, economic view, decision view, risk view, etc.

This document states only that there exists a minimum set of model views necessary to present sufficient material to ensure the architectural concerns for completeness, consistency, and integrability of enterprise architecture and models. Determining which views form that minimal set depends upon the specific enterprise context and purpose for addressing architectural concerns of stakeholders.

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5.3.14 Enterprise interoperation oriented

5.3.14.1 Support for model interoperability

An enterprise is often large and complex, resulting in many models for many purposes being necessary to describe what is happening at any one time and over time. Even small enterprise entities can need models of different kinds to satisfy distinct viewpoints and aspects of an enterprise.

Stakeholders, especially users, want these many models to be portable. They want to be able to reuse models across applications and not be dependent upon specific application and tool configuration. They want to implement technology that will improve their capability to provide for information from various models to be usable by applications and platforms throughout an enterprise.

Therefore, model representations for architectures in an enterprise context should support interoperation between models within and across organizations within the enterprise environment for both enterprise models and operations. Depending on the situation, there may be different approaches to overcome existing interoperability barriers (see ISO 11354-1).

NOTE As enterprise interactions of systems of systems become more complex, models can have limitations on their ability to predict all behaviours that occur as an aggregation of multiple complex system dynamic states. Research into complex modelling and current limitations is ongoing.

5.3.14.2 Support for process interoperability

Interoperability requires processes to communicate with the environment as well as internally with the processes of other enterprise entities. The extent and variety of successful communication will depend on the skills of the humans observing the processes and the quality of the software employed to enable the communication. Therefore, enterprise-referencing architecture shall provide the means for inter-process communication to the extent necessary to satisfy stakeholder concerns.

NOTE An enterprise-referencing architecture can support capability profiles and collaboration views that identify the communication capabilities and requirements of the processes that have a need for communication.

5.3.15 Verification and validation oriented

Enterprise architectures and models should include the specification of quality assurance and performance criteria that provide a means to assess both the verification of necessary relationships between models at adjacent extent of design or detail, i.e. whether the detail designs conform to the architectural specification, and validation of expected relationships between non-adjacent extent of design or detail, e.g. whether the operations of the enterprise satisfy the stakeholder's concerns.

NOTE Broadly speaking, validation assures the successful alignment of requirements through design to implementation thereby realizing intention and accomplishment of mission.

6 Components of enterprise-referencing architectures

6.1 Enterprise-referencing models

6.1.1 Purpose of enterprise-referencing models

Enterprise-referencing models shall describe essential and relevant characteristics of an enterprise consistent with one or more expressed viewpoints and shall match the extent of elaboration to the extent of the concerns addressed by those viewpoints. Enterprise-referencing models are tools for describing and representing an enterprise in the context of a given purpose. Such models may analyse enterprise operations, guide their engineering and manage their operations. Since enterprises are often analysed and modelled as systems, their models should conform to the relevant elements and principles of the corresponding theory of systems[63]. Models shall have explicitly stated purpose, assumptions and constraints.

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As appropriate, enterprise-referencing models shall address relevant concerns about the enterprise necessary to:

a) conceive, design, procure, and construct an enterprise consisting of any set of related chosen processes;

b) simulate the enterprise operation to verify both the model and the operation that the model represents;

c) manage and operate an enterprise so that it can meet its objectives; and

d) support an enterprise to modify, redesign, dismantle or reuse itself.

Enterprise-referencing models do not duplicate reality; they are limited approximations of the subset under consideration. Enterprise-referencing models should be as abstract as possible while meeting the needs of the modeller to address stakeholder concerns. Care is necessary to assure that models are consistent with observed or expected reality.

In a specific context, not all information available to an enterprise-referencing architecture modeller is architecturally significant, e.g. the design and implementation is not affected by the architectural specification even though information about that design and implementation is available[30]. However, the architect should not ignore the choices made during design and implementation that impact fitness-for purpose of the architecture. In fact, an as-is enterprise architecture results from those very choices made in the past and a to-be enterprise architecture often focuses on the need for different choices going forward.

In an operating scenario, the information captured by an enterprise-referencing model shall be available to humans and machines responsible for successful operations.

6.1.2 Kinds of enterprise-referencing models

6.1.2.1 Forms of enterprise-referencing models

An enterprise-referencing model consists of structured modelling elements and rules about permissible relationships between modelling elements, which convey the information that applications use to do their work. An enterprise is often large and complex and therefore has many models for many purposes. Some of these enterprise-referencing models may use model-based formalisms and some may be very informal.

Because of the diversity in model representations of an enterprise, many encoding formats can be present to meet the needs of information generators and information users. Models can be in forms such as organograms, spreadsheets, engineering drawings, process-flow data, computer aided engineering, computer-aided design, and computer-aided manufacturing files, databases, and just plain text.

Informal modelling formats make an integrated enterprise-referencing model difficult if not impossible while more formal model-based formats with appropriate model information exchange features provide better integrated enterprise-referencing model opportunities. Such integration is essential to understanding an enterprise in its entirety. As the purpose of an enterprise-referencing architecture moves from narrowly focused stakeholder concerns to encompass a wide range of concerns throughout the whole enterprise, model-based methodologies should become the norm for expressing enterprise-referencing models.

6.1.2.2 Model-based enterprise-referencing models

For model-based enterprise-referencing architectures, the representations at different segments of a life cycle or extent of genericity are often expressed as meta-representations, i.e. the models are distinct abstractions rather than the contents of a generalized enterprise model view as perceived by the model user. The enterprise-referencing model expresses either the means for generating another model more closely associated with the enterprise reality, or the modelling components from which to generate another model more closely associated with the enterprise reality.

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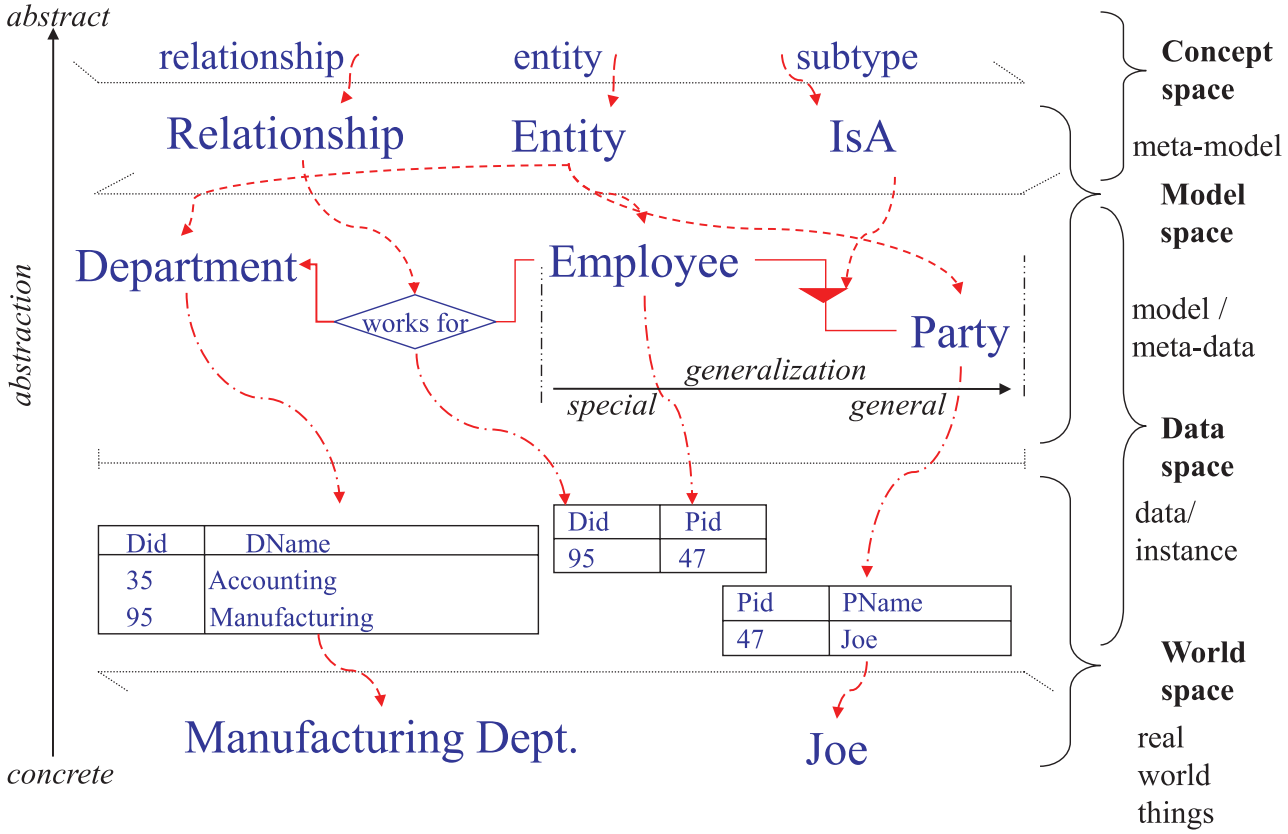
Being model-based means that there is a meta-model integral to the methodology that is used to guide the expression of application domain models. Special care is necessary when considering architectures and models with different meta-representations. To the extent possible, an enterprise-referencing architecture should align meta-representations of similar abstraction to facilitate comprehension of the underlying modelled entity[65].

Figure 1 depicts the meta-relationship abstractions for an employee database using an entity-relationship modelling paradigm.



SOURCE: Martin R. and E. Robertson, "Meta" Matters[46]. Reproduced with the permission of the authors.

Figure 1 — Meta- relationship abstractions

Sometimes one modelling meta-model satisfies model-based modelling for an entire domain dimension by providing a means for additional model detail, e.g. an information viewpoint across the entire life cycle at all three coordinates of the genericity modelling dimension.

EXAMPLE A management team recognizes that describing product functionality is an important part of enterprise-referencing architecture and identifies basic product features that an architect needs to assess for feasibility within anticipated resource constraints. In this situation, the functional model for the management team is at a different extent of abstraction than the process and resource models created by the architect to assess feasibility.

NOTE A meta-relationship exists between an architectural viewpoint and an architectural model that corresponds to the relationship between the viewpoint and the view of the models governed by that viewpoint. This meta-relationship results from an instantiation of the model to produce the content present in the view.

6.1.2.3 Views of models

A model shall include statements and descriptions of its purpose relative to concerns of appropriate stakeholder perspectives and the constraints imposed upon the modelling effort by the modelling methodology and modeller assumptions. To ensure adequate completeness and consistency, the

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governing viewpoint, these artefacts should include a minimum set of derivable model views. Further, because a view is a projection of model content for a specific purpose, an integrated model, i.e. a model composed of other models sharing a common form sufficiently expressive to capture those details that affect interoperability, provides the opportunity for a complete enterprise view rather than a view constrained by lack of interoperability among its disparate models. The number and the kind of model views for inclusion in that minimum set depends upon the methodology used and the purpose and extent of model abstraction.

Consistency is a specific problem when dealing with views for two reasons:

a) the tendency to use views as an update mechanism;

b) extent of abstraction among view elements.

Updating through a view does not assure consistency for model content because of unknown effects on the view complement, i.e. model elements not within the view and not subject to the update but changed nonetheless, e.g. the loss of referential integrity when a value changes as can occur across life cycle phase boundaries. A view containing elements of different abstraction extent presents different versions relative to an underlying enterprise reality, e.g. a conflating of data and model within the same view. Enterprise-referencing modelling and operational tools used to manipulate enterprise-referencing architectures and models shall be responsible for ensuring the consistency of model content and fidelity of model views.

NOTE Necessary model views are those that present a useful combination of activities, information, control, resources, and process capabilities to satisfy stakeholder concerns as governed by the corresponding viewpoints. Viewpoint specification in this document includes a call for several explicit architectural views and suggests mandatory compliance with a minimal set of view specifications (see 6.5).

6.2 Modelling languages

6.2.1 Requirements for modelling languages and constructs

Enterprise-referencing architectures that are model-based shall identify modelling languages or modelling constructs that allow description of enterprise operation. Modelling constructs shall allow representation of the different parts of the modelled enterprise, including collaborative interoperation with external partners, and thereby improve both modelling efficiency and model understanding.

The representational form of modelling constructs shall be consistent with the descriptive needs of people creating and using enterprise-referencing models. Therefore, different languages can exist to accommodate the aspects relevant to different model users, e.g. business users, system designers, information technology modelling specialists. In addition, modelling languages can allow the formation of basic constructs into higher order constructs, e.g. macro constructs, to enhance modelling productivity.

NOTE The standardized modelling constructs defined in ISO 19440 improve interchange of models and dialogue between enterprise modellers.

6.2.2 Expressiveness

Enterprise-referencing modelling languages shall be expressive enough to model human roles, operational processes and their functional contents as well as the supporting information, office and production technologies. Their semantics should be describable in terms of ontological theories. This suitability for formal description is especially important if architectural models are to support the enterprise operation itself, because such models need to be executable. However, natural language explanations of concepts should support the definition of the formal semantics embodied in a model as well.

6.2.3 Semantics and syntax of an enterprise-referencing model

Models, as representations of enterprises, shall carry syntax and semantics such that the content of the model is understandable to both humans and machines. The syntax of a model shall reference the

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permissible arrangements of the representations of the elements and to the permissible kinds of relations. The semantics of a model shall encompass the meanings of the elements and relations with respect to enterprise-referencing model concepts. The syntactic form and semantic content of a model may be different depending, for example, on the purpose of the model, its scope and the environment of the enterprise. As machinery takes on a larger share of enterprise operations, properly conveying model intention as well as control become more important.

6.2.4 Names, labels and glossary

Relative to purpose, context, and model constraints, the individual product, process, project, or enterprise will have its own customary names, labels and terminology. To promote understanding about programmes and other co-operative efforts, enterprise-referencing architectures and models shall provide

— a consistent glossary including a syntax and semantics for use in enterprise-engineering and integration efforts, or

— a reference to other suitable glossaries.

Enterprise-referencing architectures and models shall use the glossary content consistently across the enterprise or explicitly state differences in usage.

EXAMPLE Table 1 has three life cycle phase columns with names for each phase. These phase names are intended to describe appropriate constraints on the life cycle content, and enterprise-referencing models are expected to use the given names consistently.

Table 1 — Mapping between system life cycle phases and system activities

Role of Stakeholder	Phase		
	Plan and Build (e.g. before sell/buy/ title transfer)	**Use and Operate (e.g. after sell/buy/ title transfer)**	**Dispose and Recycle (e.g. after product is no longer useful)**
Specifies	Develop goals Define strategy Define product needs	Define support needs Define use	Define recycle/dispose needs
Creates	Develop requirements Define concept Design product Plan to produce product	Define use requirements Define support require-ments	Define recycle/dispose requirements
Uses	Procure parts Produce product Test product Ship product	Use the product Support product	Recycle product Dispose product

NOTE A particularly useful set of life cycle phase names are: domain identification, concept definition, requirements definition, design specification, implementation description, domain operation, and decommission definition. See also Annex B and ISO 19439.

6.2.5 Elements of interoperation

For each model element expressed using a modelling language, the syntax and semantics shall identify:

— form(s) of representation for the element;

— relations between the element and other model elements;

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