

Enterprise Modelling - from CIMOSA to CSE-OSA

(Computer Integrated Manufacturing to Computer Supported Enterprise)

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Abstract: CIMOSA (Computer Integrated Manufacturing Open System Architecture) has been developed during a time where the focus was on Manufacturing. However it was clear from the very beginning that its process-oriented concepts can be applied to any enterprise. This paper presents a summary of the CIMOSA concepts starting with some general remarks on enterprise modelling and a short review of the CIMOSA history. Since the emphasis in most enterprises has shifted towards heavy collaboration between individual organisations, this paper also addresses the capabilities of CIMOSA in this inter-organisational field of enterprise modelling. Details of the extension of the CIMOSA specification are briefly discussed and presented in a separate paper (to be published) that describes the capabilities for both intra and inter-organisational communications including the proposed extension of the CIMOSA templates.

Introduction

Enterprise modelling has been a subject of trial and error throughout human history. Even early civilisations identified organisational models by assigning responsibilities and authorisation to hierarchies of people. Such position assignments have been made public by titles, uniforms and status symbols like castles, palaces, etc. and a clear assignment of numbers of subordinates. But with the increase of enterprise complexity in the military and even more in the commercial area the need for a common understanding among participants about their common enterprise lead soon to the widely used form of organisation chart to document the organisational model of the enterprise.

However any enterprise requires also some more or less rigor thinking about the possible thread of actions to take place during the undertaking as well as of needed supply and resources. Even Alexander the Great, one of the most famous conquerors in World History, must not only have had a vision of the expected result of his extraordinary enterprise - the creation of the largest empire of the ancient world, but of required supplies, resources and to some extent of the thread of actions as well. His enterprise models may have resided mainly in his head and any communication on the subject with his subordinates was probably entirely verbal.

For a long time, documentation of this type of enterprise models has only be done in pieces by creating list of supplies, parts lists, shipping lists, etc. Only the division of work as described by Adam Smith [1] required a recording of the threat of actions or a work plan needed for the production of industrial products.

The Need for Enterprise Modelling

Work plans have become the focus of many academic studies continuously trying to increase production productivity by decreasing the time needed for the different tasks. In the early 50s of the last century the Methods-Time-Measurement (MTM) [2] became the recognised method for such evaluations and a measure for improvements. But it was soon recognised that efficient production planning and control needed a much more detailed description, not only of the individual tasks, but of the production process as a whole. With such a description the processes could be simulated and optimised prior to their implementation. In addition enterprises have become rather complex organisations that need ICT support for the managing tasks as well.

The Solution

The advent of the computer provided a tool that allowed recording and housekeeping of large amounts of data. This allows description and simulation of production as well as management processes and evaluation of potential alternatives prior to their implementation.

The tasks in any process in any enterprise can be described as enterprise activities that need inputs and require resources to produce results. Particular control information provide for the rules under which the actions are to be carried out by the resources. In addition control output information provide for further downstream control as well as for documentation of the action itself (e.g. duration, quality, others). The set of tasks/activities relating to one end product make up a production process and the

dynamic behaviour of that process identifies the sequence of actions to take place in the course of the product creation.

Starting with ERA and SADT [3/4] in the 70's of the previous century, the IDEF enterprise modelling language used by the ICAM program in the USA [5/6] became a language used by many industries. Since then numerous languages have been developed with emphasis on different aspects of process- and enterprise modelling and some have been standardised by industry consortia (e.g. UML; developed by OMG [7]) or standardisation bodies CEN/ISO (EN/IS 19440 based on CIMOSA [8]). A well recognised Book about enterprise modelling has been written by Francois Vernadat [9].

CIMOSA History

CIMOSA has been developed by the European project AMICE as an Open System Architecture for the manufacturing industry. It is the result of a 10 Year long collaborative development effort of up to 30 European Organisations both from Industry and Academia, supported by the European Commission under the European Strategic Program for Research and Development in Information Technology (ESPRIT). CIMOSA contains a number of concepts that enable the modelling of enterprise processes in a computer supported environment [10/11]. With the main development carried out in the 80s and 90s of the last century, additional efforts especially by the IFAC/IFIP Task Force [12/13] have lead to harmonisations with other developments in Europe and the USA. The work of the Task Force resulted in a Generalised Enterprise Reference Architecture and Methodology (GERAM) that has been the base for the first international standard ISO IS 15704 '*Industrial automation systems — Requirements for enterprise-reference architectures and methodologies*' [14].

Cooperation with the USA during the early 90s resulted in joined workshops for further harmonisation between the European work and the ongoing work in US Government supported programs. Results have been presented in the first International Conference on Enterprise Integration and Modelling Technology (ICEIMT) [15]. These efforts continued after the completion of the European Project AMICE and with a series of international workshops and presentation of the results at further ICEIMT conferences in 5-year intervals [16-18].

Two additional standards have been developed jointly between the International Standards Organisation (ISO) and the Comité Européen de Normalisation (CEN = Committee for Standardization): CEN/ISO 19439 '*Enterprise integration - Framework for enterprise modelling*' [19] and CEN/ISO 19440 '*Language Constructs for Enterprise Modelling*' [20]. Both of these standards are influenced by or based on CIMOSA

CIMOSA Concepts

The different concepts are represented in a *Modelling Framework* that provides a common structure for semantic unification within and across enterprises. The framework is represented as a three-dimensional structure covering the enterprise life cycle, allowing for four different information views on enterprise information and providing three levels of instantiation of the building blocks of the modelling language. Figure 1 shows the frame-

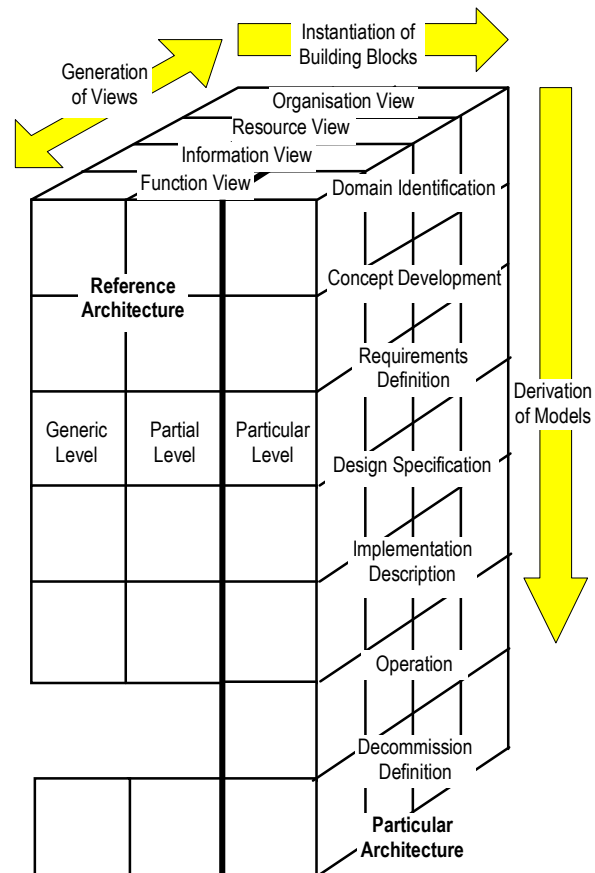


Figure 1: Overview of the Modelling Framework¹

¹ According to GERAM (Generic Enterprise Reference Architecture and Methodology) (12)

work as the extended by the IFAC/IFIP Task Force and represented in CEN/ISO 19439.

The three phases of the life cycle dimension of the original CIMOSA Framework have been amended according to the consensus reached in the Task Force showing 7 phases of the enterprise evolution (its life cycle) and the corresponding model. The one-model concept of CIMOSA allows to capture the information relevant for the different life cycle phases and continuously build up the process model from the base definitions of the enterprise through its requirements, design and implementation ending with a model that describes the operation of the complete or part of the enterprise and may even be used for its decommission. Tables 1-3 describe the different dimensions of the modelling Framework².

Model derivation is not a waterfall process per se. It will useable be iterative, amending or correcting decisions made at a higher level. Also any As-Is analysis will start at lower levels like requirements/design or even implementation description.

Table 1: Derivation of Model dimension of the Modelling Framework

<i>Level Name</i>	<i>Description</i>
Domain identification	identifies the enterprise domain to be modelled with respect to its business objectives, the domain inputs and outputs, and their respective origins and destinations ³
Concept definition	defines the business concepts of an enterprise domain to be employed in realizing its business objectives and its operation, including the necessary domain inputs and outputs
Requirements definition	defines what enterprise operations are needed and in turn what is required to enable those operations, both being without reference to implementation options or decisions
Design specification	specifies the business processes, together with capabilities and rules, that shall be performed to achieve the requirements
Implementation description	describes the final set of processes, resources and rules implemented to achieve the desired operational performance for execution of business processes and enterprise activities specified in the design specification phase
Domain operation	encompasses the operational use of the enterprise domain model
Decommission definition	defines the final state of a decommissioned operational system and all its components for a particular enterprise domain, and the processes employed to conduct the decommissioning so enabling re-use or disposition of those components

The view dimension provides for ease of use enabling a particular user to see only those parts of the model relevant for him and hides all other information. The listed four views have been identified as the most important ones, but other views may be defined. All views require modelling tool support.

Table 2: Generation of View dimension of the Modelling Framework

<i>View Name</i>	<i>Description</i>
Function/Process view	enables the representation and modification of the processes of the enterprise, their functionality, behaviour, inputs and outputs
Information view	enables the representation and modification of the information of the enterprise; it is organized as a structured set of enterprise objects that represent the information-related entities of the enterprise (material and information) that were identified in the function view
Resource view	enables the representation and modification of enterprise resources; it is organized as a structured set of enterprise objects representing the set of resources required to execute enterprise operations
Organization view	enables the representation and modification of the organizational and decisional structure of the enterprise and the responsibilities of the individuals and organizational units within the enterprise

The first two levels in the instantiation dimension in Table 3 provide the language objects needed to create the particular models that describe the model evolution according to the phases identified in Table 1. The objects at the first level are the basic language Building Blocks described in the follow-

² Adapted from CEN/ISO 19439

³ Enterprise domain can be a set of organisations, a particular organisation or any part of both.

ing section. The partial level holds aggregations of those basic objects that represent types of partial models re-useable in the modelling process through personalisation for the particular enterprise. The resulting model is presented in the particular level.

Table 3: Instantiation of Building Blocks⁴ dimension of the Modelling Framework

<i>Level Name</i>	<i>Description</i>
generic level	a collection of generic modelling language constructs for expressing descriptions that can be used to generate models at the partial and particular levels
partial level	a collection of partial models that consist of a set of related modelling language constructs and/or other partial models, which are applicable to a specific type of industry segment or industrial activity
particular level	an enterprise model representing a particular enterprise

Modelling Language

The building blocks of the modelling language can be represented in an object oriented way. Table 4 shows the corresponding mapping of the CIMOSA modelling language (standardised in CEN/ISO 19440).

Table 4: Mapping between CIMOSA Modelling Language and Object-Oriented Terminology⁵

<i>Structuring Concepts</i>	<i>CIMOSA Business language Modelling Constructs</i>				
Meta Model	CIMOSA Object Class				
	Generic Modelling Object (Modelling Object Type)				
Object Class	Business Process, Event	Enterprise Activity	Enterprise Object (Object View)	Resource (Functional Entity) Capability Set (Operational Role)	Organisation Unit Person Profile (Organisational Role)
Element	Behavioural Rule	Functional Operation	Information Element	Capability, Resource Element	Organisation Element
View	Function/Process		Information	Resource	Organisation

The lower row in table 4 shows how these building blocks support the four views identified in the modelling framework. The following table describes the functionality of these building blocks.

Table 5: Functionality of Building Blocks⁶

<i>View Name</i>	<i>Building Blocks</i>
Function/Process view	<p>Enterprise Domain</p> <p>Event: represents a solicited or unsolicited fact indicating a state change in the enterprise or its environment. Used to trigger Business Processes.</p> <p>Business Process: represents an ordered set of sub-Business Processes and/or Enterprise Activities that can be executed to realize one or more given objectives of an enterprise or a part of an enterprise to achieve some desired end-result</p> <p><i>Behavioural Rule:</i> describe the behaviour of a Business Process by a set of behavioural rules, which control the sequence of Enterprise Activities</p> <p>Enterprise Activity: represents a certain part of enterprise functionality within a process and identifies the inputs needed for its execution and the outputs created as a result</p> <p><i>Functional Operation:</i> represent a part of the functionality of an Enterprise Activity, which has been decomposed into a number of ordered transformation functions.</p>
Information view	<p>Enterprise Object: represents the set of information in the enterprise that describes a generalized real or abstract entity that can be conceptualized as being a whole</p> <p>(Object View): subset of the Enterprise Object attributes relevant in a particular application</p> <p><i>Information Element:</i> descriptive properties of Enterprise Objects</p>
Resource view	Resource: represents the provided capabilities required to execute an Enterprise Activity

⁴ Renamed 'Modelling Language Constructs' in CEN/ISO

⁵ Adapted from CIMOSA Formal Reference Base

⁶ Adapted from CEN/ISO 19440

	<p>(Functional Entity): a specialization of the Resource construct, which represents an aggregation of Resources and the related part of Person Profiles (provided Operational Roles) able to perform, completely on its own, a (class of) functional operation(s) required by an Enterprise Activity or part thereof, and to communicate with the related control Capability Set:</p> <p>Capability Set: represents the collection of capability characteristics (expressed as capability elements) of either a Resource (its provided Capability) or an Enterprise Activity (its required Capability)</p> <p>(Operational Role): specialization of Person Profile that represents the relevant human skills and responsibilities required to perform those operational tasks that are assigned to the particular Operational Role.</p>
Organization view	<p>Organisation Cell⁷: represents an entity of the organizational structure of an enterprise that is described by attributes representing properties of the organization and references to lower level organizational entities</p> <p>Organisation Unit⁸: represents a set of personal capabilities, skills and responsibilities that are required by an Organizational Unit or an Enterprise Activity or both, and that are provided by a person</p>

Templates⁹

Building blocks are represented by templates that allow to capture the information needed for the description of enterprise models. This information may be provided by users, or be generated from company data bases. The template is provided to guide current CIMOSA users and architects.

Enterprise Domain

Template Header
<i>General information:</i> Type ¹⁰ , Identifier, Name, Design Authority
Template Body
<p><i>Descriptive Properties:</i> Description, CIMOSA Compliant, Objectives, Constraints, Processes, Object Views (Inputs/Outputs)</p> <p><i>Relational Properties:</i> Boundary (Origin and Destination of Domain Inputs and Outputs), Events</p> <p><i>Domain Characterisation¹¹:</i> Mission, Vision, Values</p> <p><i>Domain Operation¹⁰:</i> Strategies, Policies, Operational Concepts, Business Plans, Performance Indicators</p> <p><i>Decisional Authority¹⁰:</i> Function, Level</p> <p><i>Operational Relationship^{7,10}:</i> Responsibility, Authority</p>

Domain Relationship¹²

Template Header
<i>General information:</i> Type, Identifier, Name, Design Authority
Template Body
<p><i>Descriptive Properties:</i> Description, Names (of involved domains), Involved Object Views (ID, Name, from, to, Frequency), Involved Events (ID, Name, from, to, Frequency)</p> <p><i>Relational Properties:</i> none</p>

⁷ renamed 'Organisation Unit' in CEN/ISO 19440

⁸ renamed 'Person Role' in CEN/ISO 19440

⁹ Partly aligned with CEN/ISO 19439

¹⁰ Renamed 'Construct Label' in CEN/ISO 19439

¹¹ Defined in CEN/ISO 19439 only

¹² Not part of CEN/ISO 19439

Domain Process¹³ /Business Process

Template Header
<i>General information:</i> Type, Identifier, Name, Design Authority
Template Body
<i>Descriptive Properties:</i> Description, Objectives, Constraints, Declarative Rules, Inputs (Function, Control, Resource), Outputs (Function, Control, Resource), Performance Indicators ¹⁴ , Ending Status, Behavioural Rules ¹⁵ , Priority, Graphical Representation <i>Relational Properties:</i> Where Used, Part of ¹³ , Comprises ¹⁶ , Events <i>Operational Relationships</i> ¹³ : Responsibility, Authority

Behavioural Rules (no template defined)

When (triggering condition) Do action)

Set of Behavioural Rules¹⁷

- process triggering	- spawning	- completion
- forced	- rendezvous	- run-time choice
- conditional	- looping	- unordered set

Objective/Constraint¹⁸

Template Header
<i>General information:</i> Type, Identifier, Name, Design Authority
Template Body
<i>Descriptive Properties:</i> Description, Subject, Target, Values, Validity <i>Relational Properties:</i> Inherited from

Declarative Rule¹⁷

Template Header
<i>General information:</i> Type, Identifier, Name, Design Authority
Template Body
<i>Descriptive Properties:</i> Description, Set of Conditions, Set of Rule Elements <i>Relational Properties:</i> Imposed on, Comprises (Objectives, Constrains)

Event

Template Header
<i>General information:</i> Type, Identifier, Name, Design Authority
Template Body
<i>Descriptive Properties:</i> Description, Related Object Views, Time Stamp, Priority <i>Relational Properties:</i> Generated by, Triggers <i>Operational Relationships</i> ¹⁷ : Operation Responsibility, Operation Authority

¹³ Not part of CEN/ISO 19439

¹⁴ Defined in CEN/ISO 19439 only

¹⁵ Renamed 'Process Behaviour' in CEN/ISO 19439

¹⁶ Renamed 'Consists of' in CEN/ISO 19439

¹⁷ Not defined in CEN/ISO 19439

¹⁸ Not part of CEN/ISO 19439

Enterprise Activity

Template Header
<i>General information:</i> Type, Identifier, Name, Design Authority
Template Body
<p><i>Descriptive Properties:</i> Description, Objectives, Constraints, Declarative Rules, Required Capabilities, Performance Indicators¹⁹, Inputs (Function, Control, Resource, Events¹⁸, Channels), Outputs (Function, Control, Resource, Events¹⁷, Channels), Ending Statuses, Behaviour¹⁸, Duration¹⁸ (Average, Minimum, Maximum)</p> <p><i>Relational Properties:</i> Where used, Consists of¹⁸</p> <p><i>Operational Relationships</i>¹⁸: Responsibility, Authorisation</p>

Different types of Enterprise Activities may be defined that identify inputs and outputs relevant for the particular functionalities. Such building blocks would be examples of the content of the partial levels identified in the framework shown in Figure 1.

The types shown in the table 6 are only illustrative examples of families of Enterprise Activity Types that may eventually exist. They have not been approved as official CIMOSA Building Block Types.

Table 6 List of potential Enterprise Activity Types²⁰

Category 0	Category 1	Category 2	Category 3
Management Oriented	- Plan	- Analyse	
		- Define	
	- Control		
	- Monitor	- Internal	
		- External	
	- Report	- Display	
		- Hard copy	
Operation Oriented	- Develop	- Design	- Draft
			- Detail
		- Qualify	- Simulate
			- Test
	- Produce	- Make	- Fabricate
			- Assemble
		- Move	- Transport
			- Handle
		- Rest	- Store
			- Wait
		- Verify	- Inspect
			- Test
			- Measure
	- Market	- Acquire	
		- Sell	
		- Distribute	
		- Service	
Support Oriented	- Install		
	- Maintain		
	- Set-up		
	- Repair		

¹⁹ Not part of CEN/ISO 19439

²⁰ Defined in CEN/ISO 19439 only

Activity Behaviour (no template defined)

Activity Behaviour is an algorithm which describes how to control the execution of Functional Operations to perform a piece of functionality in the Design Specification Model.

Table 7 Major Declarations²¹:

Pre Condition	Body	Post Conditions
Conditions before execution	Execute Functional Operations according to specified control algorithm	Conditions after execution

Ending Status (no template defined)

Ending Status of an Enterprise Activity (respectively, a Business Process) is a value describing one of the possible termination states and required for further processing in the relevant set of Behavioural Rules

Table 8 Ending Statuses:

Finished	Terminated	Abandoned
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Enterprise Object

Template Header
<i>General information:</i> Type, Identifier, Name, Design Authority
Template Body
<i>Descriptive Properties:</i> Description, Properties (description, property name, property value, related to, cardinality), Integrity Rules, Constrains ²² <i>Relational Properties:</i> ISA, Part of, Consists of ²¹ , Related to ²¹ <i>Operational Relationship</i> ²¹ : Responsibility, Authorisation

Object View

Template Header
<i>General information:</i> Type, Identifier, Name, Design Authority
Template Body
<i>Descriptive Properties:</i> Description, Nature (Physical/Information), Properties, Attributes ²¹ , Constraints, Events ²¹ , Integrity Rules <i>Relational Properties:</i> Leading Object, Related Objects, External Schemata <i>Operational Relationship</i> ²¹ : Responsibility, Authorisation

Object Relationship²⁰

Template Header
<i>General information:</i> Type, Identifier, Name, Design Authority
Template Body
<i>Descriptive Properties:</i> Description, Originator, Functionality <i>Relational Properties:</i> Related to

²¹ Not part of CEN/ISO 19439

²² Defined in CEN/ISO 19439 only

Capability Set

Template Header
<i>General information:</i> Type, Identifier, Name, Design Authority
Template Body
<i>General information:</i> Description, <i>Capability Elements:</i> Function related, Object related, Performance related, Operation related <i>Relational Properties:</i> Where used

Resource

Template Header
<i>General information:</i> Type, Identifier, Name, Design Authority
Template Body
<i>Descriptive Properties:</i> Description, Capability Set, Class (functional Entity or Resource Component) <i>Operation set:</i> List of Functional Operations, Object Views <i>Relational Properties:</i> Part of, Consists of

Organisation Cell²³

Template Header
<i>General information:</i> Type, Identifier, Name, Design Authority
Template Body
<i>Descriptive Properties:</i> Description, Organisational Level <i>Operational Authority/Responsibility:</i> Process, Information, Resource <i>Relational Properties:</i> Assigned Cells, Assigned to

Organisation Unit²⁴

Template Header
<i>General information:</i> Type, Identifier, Name, Design Authority
Template Body
<i>Descriptive Properties:</i> Job Description, Skill Profile, Responsibilities/Authorities, associated Functional Entities <i>Relational Properties:</i> Assigned to Organisation Unit

The Use of Enterprise Models

For a long time enterprise models have mainly been concerned with process planning and design. They have been used for process optimisation through simulation and improvement evaluations. Also employee training has been improved using enterprise models since they provided a consistent view of relevant parts of processes and their environment.

But in the meantime it has been realised that enterprise models could also be used for process monitoring and control. Connecting the model with the enterprise data bases enables 'quasi continuous' monitoring of process performance. The actual performance parameters become available throughout process execution time. This allows corrective actions any time convenient during the progress of the process. This may include changes in the execution path (its control) as well.

But with the increase of inter-company collaboration and the need for inter-organisational transactions, the heterogeneity of IT systems has become a real barrier. To exchange information items between foreign IT systems needs a common understanding about the meaning (semantic) of the information item as well as about its format and syntax.

But enterprise models usually contain all information relevant in enterprise operations and may therefore being used to collect information about the items to be involved in inter-organisational exchange. If this information could be accessed it would be a significant step towards achieving

²³ Renamed 'Organisation Unit' in CEN/ISO 19439

²⁴ Renamed 'Person Role' in CEN/ISO 19439

interoperability in heterogeneous environments. The subject has been addressed in a separate paper [21] (to be published).

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