# Enterprise Modelling and Integration
## *From Fact Modelling to Enterprise Interoperability*

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**Abstract:** Enterprise Modelling and Integration has evolved over the last decades from entity-relationship and activity modelling to object and flow modelling as well as from pier-to-pier system integration to inter-organisational exchanges enabling various forms of electronic commerce. The next challenge is Enterprise Interoperability, i.e. seamless integration in terms of service and knowledge sharing. The paper discusses modelling and integration issues to progress towards Enterprise Interoperability and shows how the CIMOSA architecture can be revised to host these emerging techniques and standards.

## 1 INTRODUCTION

*Enterprise Modelling* (EM) is the art of externalising enterprise knowledge, which adds value to the enterprise, be it a single enterprise, a private or government organisation, or a networked enterprise (e.g. extended enterprise, virtual enterprise or smart organisation). *Enterprise Integration* (EI) deals with facilitating information flows, systems interoperability and knowledge sharing among any kind of organisation. *Enterprise Interoperability*, as one of the many facets of EI, provides two or more business entities (of the same organisation or from different organisations and irrespective of their location) with the facility to exchange or share information (wherever it is and at any time) and to use functionalities of one another in a distributed and heterogeneous environment (Kosanke, Nell, 1997, OAG. OAGIS, 2001, Petrie 1992, Vernadat, 1996).

With the emergence of A2A (application-to-application) and X2X technologies in business (B2B: business-to-business, B2C: business-to-customer,

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C2C: customer-to-customer...) as well as in governments (G2B: government-to-business, G2C: government-to-citizen, G2G: government-to-government, G2N: government-to-non government organisations), there is a need for sound and efficient methods and tools to design and operate efficient integrated systems made of autonomous units.

In this context, EM provides a *semantic unification space* at the corporate level where shared concepts can be properly defined, mapped to one another and widely communicated in the form of enterprise models (Goranson, 1992).

This position paper first briefly reviews the current state of EM and EI and then probes the future in terms of their evolution before indicating how the CIMOSA framework can be revised to cope with these evolutions.

## 2 ENTERPRISE MODELLING & ENGINEERING

**What it is:** *Enterprise Modelling* is concerned with representing the structure, organisation and behaviour of a business entity, be it a single or networked organisation, to analyse, (re-)engineer and optimise its operations to make it more efficient. Enterprise Modelling is a crucial step both in Enterprise Engineering and Enterprise Integration programmes (Vernadat. 1996).

*Enterprise Engineering* (EE) is concerned with designing or redesigning business entities. It concerns all activities, except enterprise operation, involved in the enterprise life cycle, i.e. mission identification, strategy definition, requirements definition, conceptual design, implementation description, installation, maintenance and continuous improvement as defined in PERA and GERAM (IFAC-IFIP Task Force, 1999, Williams 1992). It mostly concentrates on engineering and optimising business processes in terms of their related flows (materials, information/decision and control), resources (human agents, technical agents, roles and skills) as well as time and cost aspects. EM techniques for EE should therefore support at least representation and analysis of *function*, *information*, *resource* and *organisation* aspects of an enterprise (AMICE, 1993, IFAC-IFIP Task Force, 1999, Vernadat. 1996).

As advocated in the Zachman Framework (Sowa, Zachman, 1992), the objective of EM is to define the six perspectives of *what, how, where, who, when* and *why* of the *Enterprise Model, System Model, Technology Model* and *Component* level of an enterprise. The what defines entities and relationships of the business entity, the how defines the functions and processes performed, the where defines the network of locations and links of entities and agents, the who defines agents and their roles, the when defines time aspects

and the schedule of events, and the why defines the strategy of the enterprise.

**What needs to be modelled:** The following aspects are concerned (AMICE, 1993, IFAC-IFIP Task Force. 1999).

- Function aspects: functional domains, triggering events, business processes (or control flows), enterprise activities (or process steps)
- Information aspects: enterprise objects, object relationships (semantic and user-defined links), object flows, object states
- Resource aspects: doers (human and technical agents), resource components, resource capabilities and/or competencies, roles
- Organisation aspects: organisation units, organisation cells (or decision centres), responsibilities, authorities
- Temporal and causal constraints

These are the usual modelling constructs found in prominent EM languages (ARIS, CIMOSA, GRAI, IDEF, IEM...) as reviewed in (Vernadat. 1996).

**What for:** The enterprise models must provide abstract representations of the things of the organisation being analysed with enough precision and in a way which lends itself to computer processing to support:

- Enterprise Reengineering / Process Improvement (establishing the business-process map, simplifying and reorganising some processes, optimising use of resources, simulating enterprise behaviour)
- Workflow design and management (to automate critical processes)
- Tuning enterprise performances (mostly in terms of costs and delays but also quality, reactivity and responsiveness)
- Management decision support ("what if" scenarios, simulating planned situations, forecasting, etc.)
- Enterprise integration (i.e. seamless exchange across the system to provide the right information at the right place at the right time)

**Enterprise Knowledge Management:** Enterprise modelling is a form of enterprise knowledge representation method in the sense that it captures, represents and capitalises basic facts and knowledge about the way the enterprise is structured, organised and operated (mostly surface knowledge).

According to G. Mentzas, Enterprise Knowledge Management (Tiwana, 2000) is a new discipline for enabling individuals, teams and the entire organisation to *collectively* and *systematically* create, share and apply *corporate knowledge* to better achieve organisational *efficiency*, *responsiveness*, *competency* and *innovation*. Thus, there is a need to also address deep knowledge.

Within an enterprise, knowledge is exhibited at various levels. It is in the mind of people (individual level), within team structures (team level), encap-

sulated in business processes and rules (organisational level) and linked to inter-organisational interactions (environment level).

Knowledge is usually classified as *tacit* (formalised as a theory or expressed in a structured language/notation) or *implicit* (individual feeling or known by humans but not formalised in a theory or in a structured model).

Nonaka has proposed a cyclic model of knowledge emergence and consolidation within an organisation (Tiwana, 2000). The model is a cycle made of four steps: *socialisation* (tacit know-how becomes shared know-how), *externalisation* (shared tacit know-how becomes codified knowledge), *combination* (codified knowledge becomes enterprise knowledge), and *internalisation* (enterprise knowledge becomes individual tacit know-how).

**Evolution of Enterprise Modelling and future issues:** The origins of Enterprise Modelling can be set back to the mid-70's when several diagrammatic methods were proposed for information system analysis and software development. The early methods can be qualified as *fact modelling* methods in the sense that little or poor semantics of the enterprise was captured. Pivot concepts taken into account were the concepts of enterprise *entities*, *relationships* among entities and *activities* made of sub-activities. The models produced only represent static facts. Pioneering methods are the entity-relationship model of P.P.S. Chen and the SADT method of D.T. Ross, also known as IDEF0, (Vernadat, 1996).

They were soon followed in the 80's by *flow-charting* methods combining ideas of the two previous ones but in addition depicting the flow of processing activities (SSAD by Gane and Sarson, Yourdon's notation, DeMarco's notation, MERISE in French spheres) (Martin, McClure, 1985). For CIM, IDEF and GRAI methods appeared (Vernadat, 1996). Time aspects were missing in such models.

At the same period, a lot of more fundamental work was carried out on (1) *semantic models* (e.g. extended entity-relationship model, semantic networks, frames, binary model) to capture more of the semantics of data or for knowledge representation, and (2) on *formal models* to analyse system behaviours (e.g. Petri nets, timed Petri nets, coloured Petri nets, state-charts).

The 90's have been dominated by two complementary trends, which have seriously impacted and boosted EM: business process (BP) modelling and object-oriented (OO) modelling. *BP modelling* focuses on business processes and related concepts: *events*, *activities*, *roles*, *resources* and *object flows*. Many of the common EM tools and approaches have emerged from this trend (CIMOSA, IDEF3, ARIS, IEM and the workflow technology). *OO modelling* focuses on the abstract concept of objects and brings structuring modelling principles, e.g. object uniqueness, property inheritance, aggregation mechanisms, and reusability. The prominent method in the field is UML (Unified Modelling Language), which has become an OMG and ISO stan-

dard and has supplemented OMT (Object Modelling Technique) (ISO/IEC DIS 19501-1, 2000).

Current modelling tools are quite good at modelling structured business processes, i.e. deterministic sequences of activities with related object flows and associated resources (e.g. ARIS Tool Set, FirstSTEP, etc.). However, they need to be extended in several ways. Among these, we can cite:

- *Socio-organisational aspects*: More research work and extensions to commercial tools are required in terms of modelling human roles, individual and collective competencies, decision centres. To this end, a competency model has recently been validated in industry and proposed to extend CIMOSA constructs (Berio, Vernadat, 1999, Harzallah, Vernadat, 2002).
- *Weakly structured workflow*: Structured business process and workflow system implementations tend to rigidify the enterprise, i.e. to automate processes in an inflexible way. Modern tools should be able to cope with weakly or ill-structured processes, i.e. processes for which the exact control flow sequence is not fully known. Three essential constructs have been proposed to this end but not yet implemented in commercial tools: AND construct (the process step is made of *n* activities that must all be done but the execution order of which will be decided at run-time), XOR construct (there are *n* activities in the process step but only one will be executed, the choice of which will be decided at run-time), and the OR construct (*k* among *n* activities will be done in the process step at run-time but the selection will be decided at run-time) (Berio, Vernadat, 1999). Another interesting problem concerns the modelling of the decision knowledge associated to each case, which is also a research issue (El Mhamedi, et al, 2000).
- *Inter-organisational Interaction and Co-ordination* aspects: The modelling of networked organisations and supply chains requires that new constructs be proposed to cope with such structures.
- *EM ontologies*: Because there are different ways of representing the same concepts, there is the need to have an ontology of enterprise modelling concepts (specialised by industrial sectors, application domains, tools, and so on) (ACM, 2002). Examples of such ontologies for enterprise modelling are the TOVE ontology (Fox, Gruninger, 1998) or the ontology for PSL (Process Specification Language) (Schelenoff, et al, 2000). The UEML (Unified Enterprise Modelling Language) initiative of the IFAC-IFIP Task Force on Enterprise Integration is another one (Vernadat, 2001). EM ontologies have a crucial role to play to make Enterprise Interoperability a reality in the next decades.

# 3 ENTERPRISE INTEGRATION

**Enterprise Integration:** Since the early 90's, EI has drastically evolved from specialised communication protocols (e.g. MAP, TOP, field-buses), diverse dedicated standard data exchange formats (e.g. IGES, STEP, EDI/ EDIFACT, HTML...) and complex monolithic integration infrastructures for distributed computing environments (e.g., OSF/DCE in the Unix world, OLE and DCOM in the MS Windows world and OMG/CORBA in the OO world) proposed at that time (Vernadat, 2001). Regarding Enterprise Application Integration (EAI), the state of the art is now to use *Message-Oriented Middleware* (MOM) (either in stateless or state-full mode as well as in synchronous or asynchronous mode) on top of computer networks compatible with TCP/IP (Linthicum, 2000). The middleware must provide sufficient scalability, security, integrity and reliability capabilities. Messages are more and more in the form of HTML and XML documents. The most recent trend is to switch to Java programming (JSP, EJB) and apply the J2EE (Java to Enterprise Edition and Execution) principles to build integrated collaborative systems.

On top of these, large applications are implemented according to the 3-tier client-server architecture using the web architecture and a standard protocol (HTTP). A client user can access the application on his/her PC via HTTP using a standard HTML browser. The request is sent to a web server, which concentrates all requests and passes the request to the application server (AS). The AS processes the request using its local database server.

A new trend for the development of application servers is to build them as a set of remote services accessible via the web, called *web services*. The client does not need to know where they are located on the web but can request their use at any time. Services need to be declared via WSDL (Web Service Description Language) and registered in a common web repository, called UDDI

Concerning message exchange, the trend is to make wide use of XML (eXtensible Mark-up Language) (XML, http) to neutralise data because of the ability of XML to separate the logic of documents as well as data formatting from data itself. This means that well-known data exchange formats used in industry (e.g. EDI, STEP, etc.) will soon have to be reworked in the light of XML (e.g. cXML, ebXML...).

Finally, concerning transport of messages, new protocols are being proposed including SOAP (Simple Object Access Protocol) (http://), RosettaNet (http://), Bolero.net (http://), Biztalk (http://) among others.

**Towards Enterprise Interoperability:** Broadly speaking, interoperability is a measure of the ability of performing interoperation between two or more different entities (be they pieces of software, processes, systems, or-

ganisations...). Thus, Enterprise Interoperability is concerned with interoperability between organisational units or business processes either within a large distributed enterprise or within a network of enterprises (e.g. supply chain, extended enterprise or virtual enterprise). The challenge relies in communication, co-operation and co-ordination of these processes.

# 4 CIMOSA REVISION

CIMOSA (AMICE, 1993), a pioneering Enterprise Integration architecture designed in the late 80's – early 90's, is made of three main components, namely the *Modelling Framework* (MFW), the *Integrating Infrastructure* (IIS, made of distributed computer services) and the *System Life Cycle* (SLC or deployment methodology). This architecture can be revisited as follows.

Concerning the EM Modelling Framework, it is proposed to add a modelling view to CIMOSA, called *Interaction View,* to deal with inter-organisational aspects, mostly interaction and co-ordination mechanisms between business entities making a networked organisation or supply chain. Constructs of this modelling view would include (Fig. 1):

- *Business Entity*, used to define the components (or nodes) of a networked organisation or supply chain. They can represent External Suppliers, Manufacturing Units, Warehouses, Final Assembly Units, Distribution Centres and Customers)
- *Interface*, used to define the corporate competencies and services offered by each Business Entity and the protocol to access them
- *Channel*, used to define exchange mechanisms between two Business Entities in terms of frequency, exchange mode, exchange rate, carrier, exchange cost, availability, reliability and alternatives). Two types of Channels need to be distinguished: *Communication Channels* for data/information exchanges (information flows) and *Transportation Channels* for goods exchanges (material flows).

Concerning the Integrating Infrastructure (IIS) the recommendation is to develop IIS services as Web services on top of a Message-Oriented Middleware where messages would be encapsulated in XML format and exchanged in a secured SOAP-like envelope.

Concerning the System Life Cycle, currently CIMOSA uses the life cycle defined in GERAM and approved by ISO TC 184/SC5 (IFAC-IFIP Task Force, 1999). However, this life cycle has a linear layout, which might confuse the business user because it does not show the principles of Continuous Process Improvement currently prevailing in industry and based on the Deming's Wheel philosophy (Deming, 1982). We suggest the adoption of a more

cyclic view of the SLC, presented on Fig. 2 and based on modern iterative prototyping methods used in software engineering as well as in system design and implementation.

| Interaction View | Function View | Information View | Resource View | Organisation View |
|---|---|---|---|---|
| Bus. Entity | Event | Ent. Object | Resource | Org. Unit |
| Interface | Bus. Proc. | Obj. View (or State) | Component | Org. Cell |
| Channel | Activity | Integrity rules | Capability/ Competency | Authority/ Responsibility |

Figure 1: Revised CIMOSA MFW

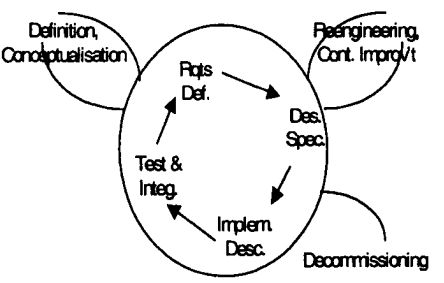


Figure 2: Revised CIMOSA SLC

# 5 CONCLUSION

Enterprise Modelling has evolved over the last three decades from fact modelling to Knowledge Management while at the same time Enterprise Integration has evolved from computer systems integration and CIM to Enterprise Interoperability and e-commerce.
This paper has provided a short overview of the field in terms of where we stand and what has to be done next. It also proposes an extension of the CIMOSA framework to host extended principles for Enterprise Modelling and Integration.

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