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ENTERPRISE ENGINEERING AND INTEGRATION IN THE GLOBAL ENVIRONMENT

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The challenges of global markets require new forms of enterprise organisation. Fluctuations in market demands, technology evolution and changing regulations require very flexible enterprise operations, capable of short time reaction. Decision-making in turn must be based on relevant and up-to-date information.

These challenges are met by organising extended, virtual and agile enterprises. Enterprise engineering and business-process-based decision support will play a major role. They will enable the forming of such enterprises by providing analysis and evaluation of partner contributions to goals and objectives as well as supporting operation re-planning in the course of exceptions handling.

The paper discusses enterprise engineering and integration as an enterprise life-cycle oriented discipline. Different aspects like impact of organisation paradigms, human roles and standardisation are presented.

1. INTRODUCTION

Enterprises are rather complex systems which have to be managed for their internal affairs, but more importantly for their many relations in the different environments in which they operate. Global markets and global competition place very stringent requirements on enterprise organisations for their ability to meet these challenges. The most important ones are operational flexibility and adaptability. Reacting and even more acting in advance must be based on relevant and up-to-date information. It is this need for relevant information which becomes of paramount importance in the decision-making processes at all levels of enterprise management. Real-time information to support the establishment, deployment and discontinuation of inter- and intra- organisational relations is key for surviving and flourish in these very competitive markets of today.

The challenges in decision support concern the identification of relevant information, easy access and its intelligent use. Building and maintaining the enterprise knowledge base and enabling its efficient use for decision support are major tasks of enterprise engineering. Enterprise integration and its subsequent operation in the global environment of customers, suppliers and regulatory bodies will heavily de-

pend on the availability and the continuous extension of this knowledge base. Business process based enterprise modelling will play an important role in creating the knowledge base and in using it for enterprise integration and operational decision support.

Business-process-based decision support will certainly make a significant contribution to the new forms of enterprise organisation and operation. It will enable the forming of extended and virtual enterprises by providing detailed analysis and evaluation of partner-business processes and their contribution to the overall goals and objectives as well as supporting re-planning and restructuring of the operation in the course of exception handling.

2. THE ORGANISATION OF ENTERPRISES

(Kosanke, et al 1999a, Vernadat, et al, 1997)
In the global environment, the product-marketing focus is shifting from trying to convince the customer to take what you have in stock because of shorter delivery, to asserting that you can deliver exactly what the customer needs where and when it is needed. The core competency of enterprises then becomes the agility to produce a product that a customer needs when it is needed rather than on having a particular variant in inventory.

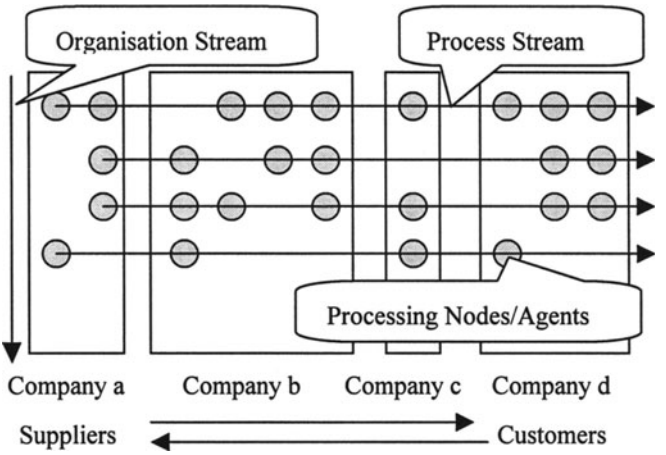

Figure 1. Inter and intra enterprise operation

Extended, virtual, and agile enterprises are created to take advantage of these new capabilities. Identifying new market opportunities, establishing the necessary partnerships with providers of the required core competency, and configuring them to an efficient and effective whole will become the management challenge of the future. Sufficient support for the decision making process with heavy time constraints is needed on all levels of the organisations. However, standards have to be in place on hardware, software, information format, and communication protocols for processes to inter-operate electronically. Compared with traditional enterprises, this becomes even more important due to the time constraints in the establishment of the new types of enterprises.

In addition, virtual-enterprises will have to negotiate contracts such as basic-ordering agreements, product liabilities, general responsibilities, etc. etc. There is a significant need to accelerate the contractual part of establishing the virtual enterprise as well and to provide a common framework for guiding the participating organisations.

To organise and operate such enterprises requires both new organisational structures and new technologies. Organisational units (e.g. of agent type), which are part of loosely linked networks and which have a rather high degree of decisional autonomy, will recognise opportunities, identify, validate and verify the needed partners and negotiate the contracts for the temporary enterprise, which will exploit the particular opportunity.

Figure 1 (Weston, et al, 1997) identifies the two types of organisation in which the organisational units will be involved. The horizontal axis shows the process streams of the virtual enterprises that describe the short-term, inter-organisational relations between the participating agents. The vertical dimension exhibits the intra-company organisation that describes the more permanent structures of traditional enterprises.

Enterprise modelling (Vernadat, 1997b) will play a significant role in the identification of the relevant information as well as for the decision support itself. The description of business processes will allow for modelling of process alternatives and their evaluation through simulation and evaluation of benefits and shortcomings.

3. THE SCOPE OF ENTERPRISE ENGINEERING

(Kosanke, et al, 1997)
Enterprise engineering is concerned with intra and inter enterprise operations and with improving their efficiency and effectiveness. This will be achieved through operation integration that means the engineering of the communication infrastructure that provides for the co-ordination and thereby co-operation between the enterprise elements involved in the enterprise operation, i.e. people, machines and computers.

The following are general definitions of enterprise engineering and enterprise integration:

Enterprise Engineering:
define, structure, design and implement enterprise operations as communication networks of business processes, which comprise all their related business knowledge, operational information, resources and organisation relations.

Enterprise Integration:
provide the right information at the right place and at the right time and thereby enable communication between people, machines and computers and their efficient co-operation and co-ordination.

With the fairly complex systems involved in the enterprise operations, the exchange of information has to be supported by Information and Communication Technology (ICT). The ICT support will facilitate the identification of relevant information and the use of current information during the decision support. Fast and efficient analysis of internal and external information, evaluation of operational alternatives through simulation and prediction of their behaviour under market constraints are some of the benefits to be obtained by ICT based enterprise integration

and decision support. It leads to better and faster decision-making and therefore increases the competitiveness of the enterprise.

This is especially needed for establishing and implementing virtual enterprises. The time window for market opportunities, which are to be exploited by a virtual enterprise, is usually small. Therefore the evaluation and matching of partner contributions must be done on short notice and with heavy time constraints. On the other hand, the analysis has to be made on a fairly detailed operational level to ensure the feasibility of interoperation between the different partners.

4. IDENTIFICATION AND USE OF INFORMATION

Identification of information and enabling its easy and timely access plays a major role in the enterprise engineering tasks. The question is how to know what is relevant information and where and how to get it in time? The identification of the relevant information can best be done through process models (Vernadat, 1996). Process models describe both the functionality and the dynamics of the enterprise and identify all the needed and produced information (e.g. orders, parts/products, resources, organisational aspects, etc.) as well as relationships with the internal and external environments.

These models can be used to make predictions about the enterprise future and thereby support the decision-making activities in the enterprise through evaluation of business processes or process alternatives. Enterprise scenarios may identify the characteristics of the addressed markets, which must be matched by the capabilities of the organisation. Such an analysis is carried out using models of the relevant business processes and simulating the enterprise behaviour in the expected market. Adapting the business process models to the market needs allows to identifying currently missing operational capabilities.

Computer supported model enactment (animation and simulation) will make possible this evaluation of the process alternatives and thereby provide for optimisation of the enterprise operations. The selected alternative will become the new process model to be used in future decision support activities, thereby, enabling a continuous up-date of the enterprise model. With the process models always describing the actual state of the enterprise, decisions are based on real data rather than on estimated or biased information and/or assumptions.

Process models may be used for decision support on any level of the enterprise organisation for strategic, tactical or operational planning. Any planning task will start from the current process models and apply its relevant time horizon and adapt for the required level of detail. The models will support the evolution of the enterprise through the life-cycle phases of its products and technology.

However models will make an even more significant contribution in exception handling support. Here the models will be used to simulate the proposed corrective process changes and to evaluate their impact on the process itself as well as on the overall operation. Such evaluations will allow to optimise the corrective actions for throughput time, cost, or any other parameter judged important for the specific occasion.

Another important benefit of the use of models is the common understanding developed in the enterprise, about the contents of the operational processes. This is achieved through the explicit representation of functionality and behaviour of the

processes with all their activities, materials, products, information, resources, organisational aspects, etc. With a standardised graphical representation, this common understanding can be obtained for cross-organisational activities as well. Such a benefit will be very significant in the establishment and operation of virtual enterprises.

5. TO MODEL THE ENTERPRISE

Models are abstractions of a given reality with the degree of abstraction depending on the intended use of the model (Figure 2). However, the same model may provide different levels of abstraction to be used for various applications. Creating a model requires methods and tools for abstraction, representation and model manipulation. Modelling methods will guide the total modelling process from the observation of a reality to model use and maintenance. Tools will support all or part of the modelling process and there may be different but compatible tools for different parts of the model life-cycle.

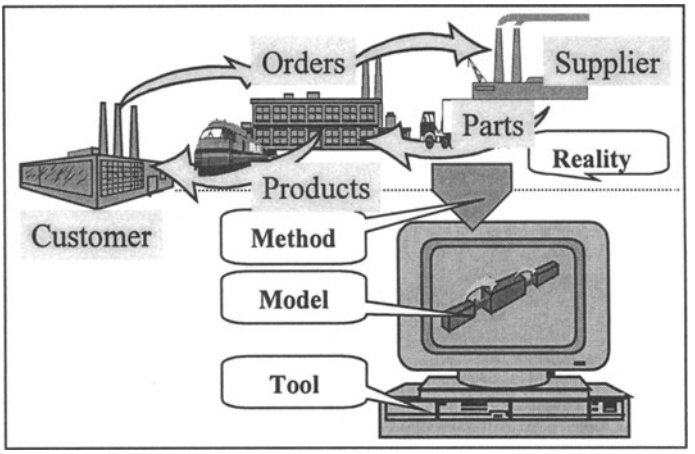

Figure 2: Enterprise Modelling

The model should not only identify the internal operations, but has to include relations to the external environment such as customers, suppliers, banks and other agencies. Enterprise models must not be built in a linear process, but rather in an iterative one with trial and error. Information will be added, either because the need for additional information has been recognised during model use, or operational alternatives are developed, validated and implemented.

Enterprise models have to recognise the life-cycle phases of the enterprise and represent the different phases of enterprise engineering from its conception to end of life according to the information needs of the many engineering tasks. The GERAM life-cycle concept (IFAC/IFIP Task Force, 1998) identifies seven different phases: Identification, Concepts, Requirements, Design, Implementation, Decommission. Modelling languages like CIMOSA (AMICE, 1993, COA, 1996) allow to representing business processes and their functional and behavioural contents. Figure 3 shows an example of a business process model representing manufacturing process which

produces parts (Product a) and assemblies (Product b). The different activities are connected via behavioural rule sets (BRS), that define the process control flow.

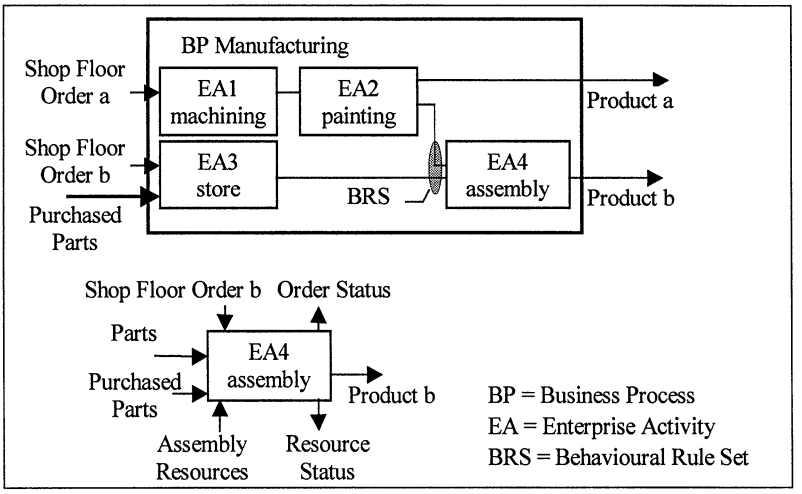

Figure 3: CIMOSA Modelling – Business Process Representation

In the lower part of Figure 3 the different information items needed and created by an activity are identified. The inputs and outputs represent functional I/Os (Parts and Product), Control I/Os (Order and Order Status) and Resource I/Os (Resources and Resource Status). In addition to the function view shown in Figure 3 at least three additional views are provided to represent collectively the information, resource and organisation aspects of the business processes.

6. THE HUMAN-ORIENTED ASPECTS

All of the enterprise aspects have human components, since the human plays a significant role in any of the enterprise-life cycle phases. Even with the emphasis on management and control there is still human involvement in the manufacturing process itself. Still, there are many areas in manufacturing operations where humans are absolutely necessary to solve unforeseen problems, to design workarounds, and to perform assembly tasks that machines cannot do as well.

There is a general need to define the role that humans play in enterprise operations, to determine how humans manage trust among their various interactions with other people and with machines, to determine how to represent a trust factor in process models, to discover how to understand the contribution of human skill, and to represent those contributions as manufacturing activities.

Modelling languages are still rather limited as far as representing the human role in the enterprise. Enterprise developers are working at the factory-floor level to find a way to better integrate humans into the processes, and higher in the organisation to better integrate the information that humans use to design the product and the process. Also being investigated is the information humans communicate back and forth to achieve understanding about what activities are needed to produce the product.

Much of this information is not written or spoken but implicit in the knowledge human carry with them about the world.

How to characterise this human element in an enterprise model? The human element is characterised by the human skills, competence, knowledge, know-how, and motivations. While these are important to recognise, they are very difficult to appraise and represent because humans are unpredictable, their work is not very repeatable, and both of these are affected continuously by the amount of stress on the human (internal and external, work and non-work related). It would be a positive step if these factors could be identified, represented, and hopefully tied to the goal of the enterprise.

7. THE ROLE OF STANDARDS IN ENTERPRISE ENGINEERING AND INTEGRATION

(Nell, 1997)

The domain of enterprise engineering and integration consists of hardware, software, communications protocols, information, frameworks, and architectures. There are things, the connections between the things, the information, and the information formats. With respect to enterprise representation, what level of concept should be standardised, from entire standard enterprises to standard names of things? Of what value are standards covering enterprise models, enterprise modelling, enterprise-reference architectures, or frameworks? Assuming that standardised enterprises and processes are not feasible, then at what level is a standard appropriate?

What seems more usable is to standardise the interfaces between components, the nomenclature, and the formats (e.g. to 'standardise' a neutral format, language or platform for information exchange) and allow the tool builders to use these standards to design software in such a way as to allow the tool user to build models of processes that communicate with each other and that are appropriate to enable the linking of process models between partners in extended and virtual enterprises.

Reference architectures identify various concepts relevant in enterprise engineering activities. Especially the life-cycle concept will allow to identifying the virtual enterprise itself, its goals and objectives and the basic operational concepts needed for producing the desired results. Operation requirements, design and implementation are further life-cycle phases identified in the reference architecture for the enterprise-engineering tasks. These tasks will allow a focus on all aspects of the enterprise operation, people, processes and technologies. The resulting models will than enable the decision support needed in the operation control and monitoring.

Tools with implemented methodologies and languages will support the people in both the enterprise engineering and the decision-making tasks during the enterprise operation. They will allow the people to create and modify process models and use them in What-If evaluation of process alternatives in the different enterprise organisations. The additional framework components will increase engineering efficiency (Generic and Partial Models) or provide support for system implementations (Modules).

However, there is a need for exchangeable and re-usable system components that will enable the flexibility and adaptability needed for the types of enterprises that will dominate the global markets in the future. The concept of component-based systems was one of the rationales of CIMOSA through its definition of Functional

Entity and Functional Operation (Weston, 1999). Standardisation has to consider the area of re-configurable systems and reusable components as a major field for standardisation work in the not to far-out future.

8. STANDARDISATION IN ISO AND CEN

(Kosanke, et al, 1999b, Shorter, 1999)
ISO on the international level as well as CEN on the European level have produced a starting set of relevant standardisation or are working on it (ISO, 1996, ISO, 1998, CEN/CENELEC, 1990, CEN, 1995, CEN, 1998). More work is required especially on the human-related aspects like model representation to the user, representation of human roles, skills and their organisational authorities and responsibilities. In addition standardisation is required in the area of business co-operations as well.

The ISO standards group to develop standards in this domain is TC184 SC5 WG1, Industrial-automation systems and integration, Architecture, communications, and integration frameworks, Modelling and architecture. WG1 envisions standards in four key areas: process representation, integrating infrastructure, a semantics-resolving utility, and representation of human involvement.

Two standards are available from TC184 SC5 WG1:

1. ISO 14258, *Concepts and rules for enterprise models* (ISO, 1996)is a high-level standard defining the nature of enterprise models with the vision that compliant models could be used to design, analyse, and eventually, operate enterprises. The rules for models are based on classic systems theory, with the assumption that an enterprise or groups of processes is basically a system and that it can be designed and analysed as such.
2. ISO 15704, *Requirements for enterprise-reference architectures and methodologies* (ISO, 1998) defines the requirements that enterprise-reference architectures and methodologies must have to be considered complete. This will be useful to those trying to improve an enterprise infrastructure or its processes, and who will create an enterprise architecture of their own that is specific to a company, industry, or purpose.

Relevant standardisation in Europe is carried out by CEN TC 310/WG1 Systems Architecture which has led to standardisation in modelling frameworks, modelling languages and services for model execution.

Three pre-standards have been issued by CEN TC 310/WG1:

1. ENV 40003, *Advanced Manufacturing Technology – Systems Architecture - Framework for Enterprise Modelling* (CEN/CENELEC, 1990), which is a partial implementation of the requirements identified in ISO 15704. It call for a clear separation of functionality and behaviour and identifies four model views to reduce complexity in model representation.
2. ENV 12204 *Advanced Manufacturing Technology – Systems Architecture – Constructs for Enterprise Modelling* (CEN, 1995) is a first version of an enterprise modelling language. It defines 11 constructs that allow to represent business processes functionality and behaviour in common way.
3. ENV 13550 *Advanced Manufacturing Technology – Systems Architecture - Enterprise Model Execution and Integration Services* (CEN, 1998) provides the functional description of model development and model execution services. It defines a platform for interoperation of enterprise models.

9. GERAM - GENERALISED ENTERPRISE REFERENCE ARCHITECTURE AND METHODOLOGIES

Starting in 1989, a Task Force carried out jointly by members of the IFAC and IFIP organisations has analysed the state of the art in enterprise reference architectures and has developed a framework that is a generalisation of the major architectures and methodologies available for the study (Bernus, et al, 1996). The results have been made available to ISO and have guided the development of ISO 15704(ISO, 1998).

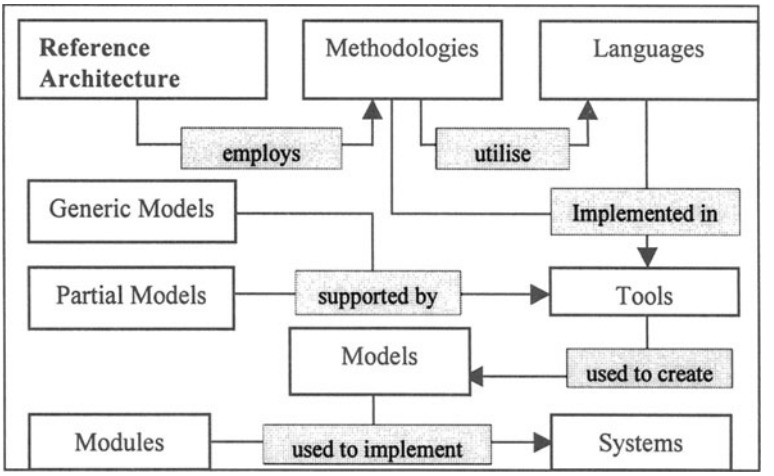

Figure 4: GERAM Generalised Enterprise Reference Architecture *and Methodologies*

The GERAM framework identifies a set of components that are essential for enterprise engineering and integration (Figure 4) which is also an annex to ISO 15704 (ISO, 1998). The enterprise reference architecture identifies the basic concepts to be used in enterprise engineering and integration (e.g. enterprise entities, life-cycles and life histories of enterprise entities). GERAM distinguishes between the methodologies for enterprise engineering and the modelling languages that are used by the methodologies to describe and model the structure, content and behaviour of the enterprise entities in question. These languages will enable the modelling of business processes and their supporting technologies as well as the roles of the human in the enterprise operation. The resulting enterprise models represent all or part of the enterprise operations, including its manufacturing or service tasks, its organisation and management, and its control and information systems.

Enterprise modelling has to be supported by enterprise engineering tools which employ methodologies and languages. The semantics of the modelling languages may be defined by ontologies, meta models and glossaries which are collectively called generic enterprise modelling concepts. The modelling process is enhanced by using partial models, which are reusable models of human roles, processes and technologies.

The operational use of enterprise models is supported by specific modules which provide prefabricated products like human skill profiles for specific professions,

common business procedures (e.g. banking and tax rules) or IT infrastructure services, or any other product which can be used as a component in the implementation of the operational system.

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