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Introduction

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1.1 ENTERPRISE INTEGRATION: THE NEXT GENERATION OF MANUFACTURING SYSTEMS AND THE NEW MANUFACTURING PARADIGM

1.1.1 Custom made products

The much touted trend of producing custom made products in the quality and with the efficiency of mass production has by today a foothold in almost every part of industry. Two major effects help this trend to gain ground: the customer's desire to get products in the exact specification desired, and the manufacturing enterprises desire to produce goods only for existing customers, rather than for would-be ones. The above two requirements underly competition because once a need is identified competitive forces will dictate to react quickly and professionally, flexibly adapting to the market need. For this reason agility and flexibility are two important properties companies strive at.

1.1.2 Virtual and extended enterprises

The traditional view of an enterprise is a hierarchical organisation. In big companies with diversified business profiles an enterprise may have meant that a branch office or a plant operated as an independent business unit.

Today very few companies design and manufacture all components in house and the view of the enterprise as an independent unit is not very adequate. In fact most of the agile enterprises cooperate with a large number of suppliers and sub contractors. Components and subassemblies are therefore manufactured outside the premises of the product vendor. More recently they are being designed in close cooperation with partners in the supply

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chain. Some suppliers are in strategic relations with a number of product vendors.

Companies must focus on the business processes that encompass the entire chain of value adding activities, called the supply chain, because it is this complete process that determines the overall result, not the process within a particular company 'A' alone. In this sense a company 'A' will have business processes of which a part are being performed outside the physical boundaries of the company. For this reason a company 'C' may be a part of the core business of company 'B' by delivering some components or subassemblies to it. The business decision, 'make or buy' or 'make or have it made' is certainly a key factor when defining an extended, integrated enterprise. Business activities (business focus) may change quickly and so should change the respective business process. The dynamism, the time dimension, of the enterprise design and implementation throughout the whole life-cycle of the enterprise is critical, and will be even more critical in the future. Virtual or extended enterprises will be formed and dissolved as quickly as the underlying business processes are changed [1]. Computer-aided tools therefore should be able to cope with the highly distributed cooperative nature of the virtual, extended enterprise concept and help companies design and redesign enterprises as the need arises.

1.2 SYSTEM BUILDING PRINCIPLES

The traditional concept of computer integrated manufacturing aimed at providing computer assistance for various elements of the product development, manufacturing and management processes. Integration in this context meant to form the interfaces and implement the information links among computer aided activities to allow direct and timely cooperation among them. Consequently one important aspect of integration has become the provision of interoperable information systems [2] that allow easy coupling between distributed elements of the material and information processing system, that is, the enterprise.

Although the above endeavour is still very timely it must be foreseen that the mere possibility of ubiquitous information technology will enable a more profound change, allowing companies to step beyond integrating their applications. Enterprise integration is the step beyond that: it asks questions about the core business processes in a organisation and concentrates on how to perform these tasks better, whatever modifications are deemed necessary to achieve this goal. Furthermore Enterprise Integration considers the process that leads to better solutions, not only the better solutions themselves.

In such a context Enterprise Integration captures and describes processes, strategies, organizational structures, resources, goals and constraints of the enterprise. It specifies the business process requirements, identifies the solution options, presents alternative designs and provides implementation paths at strategic, tactical and operational levels.

The entire business process is studied and described in terms of three inter linking networks:

1. Material flow and transformation together with service provision (i.e. the process which fulfills customer needs).
2. Information flow and transformation (knowledge and information processing in any form) that is needed to manage and control the enterprise.
3. Supporting organizational structure of people who carry out the nonautomated parts of the tasks in the two above mentioned processes. This component is essential, since people make decisions based on experience and incomplete information.

What are the best structures of business processes, organisation, and management is of course open to separate investigation: the overall method of engineering enterprises should rely on the results of the disciplines of organizational design, facility design, management science, information systems and communication. Several recently emerging research areas address the issues of which structures are suitable for efficient high quality systems design.

The ideas behind holonic manufacturing, fractal factory, agent based integration and coordination theory all address the same issue (with slightly different focus): how is it possible to design a complex enterprise, that acts as an autonomous 'agent' following its own plans to achieve its objectives while cooperating with other agents for certain common objectives? Is there a simple principle of building such an 'aware' enterprise out of participating agents? What are the means of building, coordinating, planning and operating these lower level agents (which themselves may be composed of similar, lower level agents)? Answers to these questions may dramatically reduce the complexity of today's enterprises by having to consider crucial management questions only at one level at a time.

1.3 METHODOLOGIES AND THE ENTERPRISE AS A PRODUCT

In order to manage the change process of the business effectively, enterprise integration methodologies are needed. Methodologies exist in the framework of an architecture, and rely on modelling techniques, languages, and

implementation know-how (such as previous knowledge of typical successful management-, process-, and organizational structures).

It is probably less well known that the presently widely used term of 'business process reengineering,' often referred to by consultants and understood by company executives is just one, albeit important, aspect of Enterprise Integration (EI) [3]. BPR, as it is abbreviated, focuses on the review and redesign of the core business process of an enterprise and it uses either common sense practice or professional tools offered by the EI community. There is a close cooperation between researchers of BPR and EI. What BPR does not address at this stage is the need to continuously engineer the business process, instead of just reengineering it once.

With the advent of globalization of economies, enterprises are more and more viewed as products themselves. This is quite obvious for green field companies as they are designed, built and put into operation as the customer requires. The 'product view,' however, is also true for already existing enterprises: new business priorities have to be analysed, changes have to be specified, designed and carried out. The design of an enterprise may take a long time and involve many people, therefore methodologies with a phased approach are preferred; i.e. methodologies in which the overall design can be split into implementation projects easily according to the benefit expected from each such project.

Business, manufacturing practice, organizational structure, information infrastructure keep changing to provide the most effective framework for the core business of an agile enterprise. Therefore enterprises should often be redesigned, and these modification could be significant. This creates the need for methodologies which include the element of constant renewal on a needs basis (should the need be based on internal or external factors).

To design enterprises and manage them through their entire life-cycle we need fundamental principles and powerful tools that support methodologies. An important challenge is to actually use the models of the enterprise to enact the business processes rather than keep the business process models on the shelf, since in this latter case there is little chance for the enterprise to keep an up to date picture of itself and much of the effort initially invested in modelling the processes in the enterprise is lost as reality diverges from those model. Builders of machines, electrical devices, or computer software have been using design and analysis tools for a long time and manage to keep their product models up to date and reusable, in fact these models are the basis for the entire product life-cycle. These tools, however, are product oriented and specialized to the type of product at hand. The enterprise as a product needs the matching enterprise engineering tool, which is the basis of

the enterprise's implementation and constant renewal, therefore tools needed for enterprise integration are not just more complex ones but substantially different from tools used for designing conventional products.

1.4 MAJOR PROJECTS

There are a number of large scale projects addressing the future of manufacturing industries. Here we only deal with those international efforts which aim to pool resources and skills to address major and common issues. More precisely we only refer to those which have relevance, or which even require the tools and methodologies offered by Enterprise integration architectures.

1.4.1 The Intelligent Manufacturing Systems (IMS) programme

The program was initiated by Japan in 1989 and was aimed to establish a $5 billion international research program for the next 5 years. The program was established after two years of negotiations and the completion of an international feasibility study. The identified technical themes were selected to address the main driving forces of modern manufacturing.

1.4.1.1 The driving forces

(a) Changing markets

There will be revolutionary developments which will profoundly change the manufacturing paradigm to base production on smaller units of higher quality. Advanced countries will shift from the present *make-to-stock*, sell-from-stock practice to manufacturing only the products wanted in only the quantities wanted. Companies will manufacture to actual orders only. The change in market will probably be drastic in advanced economies, from traditional growth markets to fragmented markets. Production will move closer to the consumer, since distribution cost is likely to become increasingly important.

(b) Customer orientation (flexibility)

The enormous increase in production variety and the great reduction in volume of a single product will affect all producers. Customers will have more individualistic desires. They will be interested in the details of products and services. Consumers will participate in the design and production by selecting a combination of safe and compatible components via electronic communication. This will unite *producers* and *consumers* again into '*prosumers*.' The prosumer will not see the model in a showroom since it

will be specially manufactured for her/him. The new model ideas will be viewed as electronic images. This practice will be quite common not only in the car industry, but in every manufacturing sector.

(c) Environmental requirements
The new generation of the consumer society demands that production processes should be environmentally friendly. The process should not discharge pollution to air or water. It should recirculate all material necessary for the manufacturing processes,

Design and manufacturing processes should ensure that all products and product materials should be re-used in order to minimize land fill waste.

(d) Human and social requirements
The hierarchical management structures provide clear separation of responsibilities, but different metrics are used to evaluate the performance of each function. In order to increase performance, management will instead establish a multi-functional project team whose coordination goes well beyond the traditional reporting duties. The project management team should play multiple roles to steer the project towards its vision, coordinating opinions from different functions throughout the company, stimulating innovative ideas and offering new knowledge for project members.

(e) New technologies and new production paradigms
Enterprises have already broadened their market beyond providing competitive products on competitive price. They offer products, services, technology, personnel, equipment, sites, and information (consulting, licensing, leasing, education). These trends will accelerate and will make competition more intense and difficult. Because customers will demand a wide range of products and services, rival companies must not only compete but also cooperate. It is more than likely that manufacturing will be regarded as a specialized form of *service*. This new manufacturing paradigm will integrate precision technology, information, communication technology and intellectual creativity.

1.4.1.2 Technical themes

The themes address five main areas for collaborations. The reader will note that four of them are closely related with the architectural issues. We only list the themes with their keywords as approved by the International Steering Board and refer the readers to seek further details from their regional IMS Secretariat.

- Virtual/extended enterprise issues
  (a) Information exchange across the extended enterprise
  (b) Team work

(c) Architecture for support of engineering cooperation
(d) Assignment of cost, risk and rewards

- Total product life-cycle
  (a) Models for future manufacturing systems
  (b) Environmental protection
  (c) Network Systems for information processes
  (d) Economic models
- Strategy/planning/design tools
  (a) Business process re-engineering
  (b) Analysis and development of manufacturing strategies
  (c) Planing in an extended virtual enterprise environment
- Human/organizational/social issues
  (a) Promotion of manufacturing as a discipline
  (b) Work force education and training
  (c) Organizational learning
  (d) Performance metrics
- Manufacturing processes
  (a) Clean manufacturing
  (b) Energy efficient manufacturing
  (c) Technology innovation
  (d) Flexibility

The global IMS program will be guided by an international IMS Steering Committee (ISC), with membership drawn from the participating regions. An interregional secretariat provides support for the IMS Steering Committee.

1.4.2 Technologies for business process re-engineering (a European Commisson project)

This project is part of the ESPRIT fourth framework. The mission of the project establishes the objectives 'To enable European businesses to compete more effectively within global markets by adopting and integrating best business practice in the areas of business process methodologies, information technology and human resource management.'

The documents put special emphasis on the enterprise integration issues. 'There will be a complementary activity in the integration of enterprise wide systems which will address the provision of tools, methodologies, and technology, filling strategic gaps as identified in conjunction with other activities. The research and technological development (RTD) activity will improve the potential for the next levels of business best practice.'

These two examples clearly show how important the Enterprise integrations architectures are. The authors hope that the work presented in this book will be of some value for those who are building integrated enterprises.

1.5 REFERENCES

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