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ARDIN extension for virtual enterprise integration

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Abstract

Virtual enterprise integration is the task of improving the performance of a temporary alliance of globally distributed independent enterprises that participate in the different phases of the life cycle of a product or service by efficiently managing the interactions among the participants. This is a very complex task that involves different approaches regarding technology, management and cultural elements. There are different proposals for enterprise integration (usually called Reference Architectures) that have been very useful in applications for a single-enterprise. However, they need to be adapted to support the new requirements that appear in virtual enterprise integration. This paper shows the modifications applied to ARDIN (Spanish acronym of Reference Architecture for INtegrated Development) to help in the design and management of an efficient and flexible virtual enterprise. The modifications are synthesized in a methodology, a set of reference models of best business practices, and in the design of a technological infrastructure.

Keywords: Virtual enterprise; Enterprise integration; Reference architecture; Technological infrastructure; Modeling

1. Virtual enterprises

A virtual enterprise (VE) can be considered as a temporary alliance of globally distributed independent enterprises that participate in the different phases of the life cycle of the product or service, and work to share resources, skills, and costs, supported by Information and Communication Technologies, in order to better attend market opportunities and successfully fulfill a responsible corporate strategy (Bernus and Nemes, 1999).

The creation of a VE can not only speed up the commercial transactions, but also increase the degree of integration of the value chain. In this way, every chain member can get new and better services from the other members (supplier, manufacturer, transport companies, dealer and customer) and to improve the value of the product or service that is offered to the final customer. The access to information like the state of the order, stock of certain product (either of a supplier or of a customer), etc. in any moment and from any place will accelerate the speed of reaction of the companies to market activity.

The better collaboration among each one of the members of the chain can certainly narrow the knots of union, so every member becomes more involved in the situation of the others. This increases the VE culture and makes it easier to generate a common front that works jointly for the increase of the market quota in front of other substitute materials, and in the research of innovations in the production process and in the applicability of the products. Table 1 shows some of the differences between a single and a VE.

2. Virtual enterprise integration

Virtual enterprise integration is the task of improving the performance of the whole VE by efficiently managing the interactions among the participants. As a consequence of this high level characterization, an integrated virtual enterprise should also be an awareness enterprise, meaning that changes in the internal or external environment should be dynamically reflected in its objectives, its actions, and its own composition as soon

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Table 1
Some differences between a single and a VE (adapted from Burn and Ash, 2000)

		Traditional enterprise	Virtual enterprise
	Concept	Profitability today	Profitability tomorrow
		Static	Dynamic (agile)
		Collection of functions (personnel, manufacturing, etc.) or resources (people, machines, etc.)	Add value processes and capacities
	Resources	Co-location	Competency
	Time	Sequential	Parallel
	Information	Completeness and paper distribution	Incomplete electronic sharing
	Technology	Data flow	Information access and interpersonal communications
Knowledge	Behavior	Learning	Sharing and codifying
	Beliefs	I am responsible for learning	My knowledge grows when it flows and my company benefits from my knowledge
	Values	Self-esteem	Respect and trust
Infrastructure	Physical (physical and workflow area)	JIT (just-in-time)	Lack of dependency on processes that cannot be scaled for physical or time reasons...
	Legal/explicit (business practices area)	Flat organization	Distributed responsibility for handling complaints and researching improvements...
	Cultural/social (cultural area)	Empowered, motivated workforce	Leadership is attentive to and leverages basic patterns of human behavior, group dynamics, and individual/team motivation. Synergism of business processes leveraging the diversity of business culture...

as possible, making sure that the activities of all the components contribute to the overall objective in a co-ordinate way.

However, to design and to manage an efficient and flexible VE that presents the semblance of a single-enterprise to the customers is a very complex task. It involves different approaches regarding technology, management and cultural elements.

To carry out the objective of integrating the VE, it is necessary to develop methodologies, reference models of best business practices, information infrastructures and computer enterprise engineering tools that help in the life cycle and life history of the VE.

3. Reference architectures for enterprise integration

Several efforts in the development of (1) *Enterprise Models* and (2) *Enterprises Analysis and Design Methodologies* have being carried out (Pantakar, 1995). These results are usually called Reference Architectures. A Reference Architectures is a framework, which guides you during the project of design and implementation of an integrated enterprise system by means of a structured methodology, the formalization of operations and the support tools (Burkel, 1991).

International Research and Development Groups have proposed several such architectures. Among the most well known ones are Computer Integrated Manufacturing-Open Systems Architecture (CIM-OSA), architecture carried out by the AMICE Consortium (Amice, 1993) and funded by the European Union; Grai Integrated Methodology (GIM), architecture derived from the work carried out by the GRAI Laboratory of Bordeaux University, France (Doumeingts, 1992) in several projects subsidized by the European Union; and Purdue Enterprise Reference Architecture (PERA), architecture developed by The laboratory for applied control of the Purdue University, USA (Williams, 1993).

An important part of this research theme resulted in the work of the IFAC/IFIP Task Force on Architectures for Enterprise Integration (International Federation Automatic Control International Federation Information Processing) (Bernus et al., 1996). This work was synthesized in Generalized Enterprise Reference Architecture and Methodology (GERAM) and was studied by the International Standard Organization (ISO) Working group TC184/SC5/WG1.

In this context, the IRIS Group of the University Jaume I of Castellón, Spain has been working in the ARDIN research project since 1994. The objective is to develop and validate a step forward in the state of the art of the Reference Architectures for Enterprise Integration. As a result of this work a new reference architecture was developed for the business integration; it was called ARDIN (Chalmeta et al., 2001). The existing (and in our opinion) complementary approaches were synthesized in this architecture, and new techniques, methods, models and templates were incorporated.

The ARDIN architecture is organized in *five dimensions* (see Fig. 1).

1. *First dimension:* shows the life cycle of a company and supported by this presents a methodology to

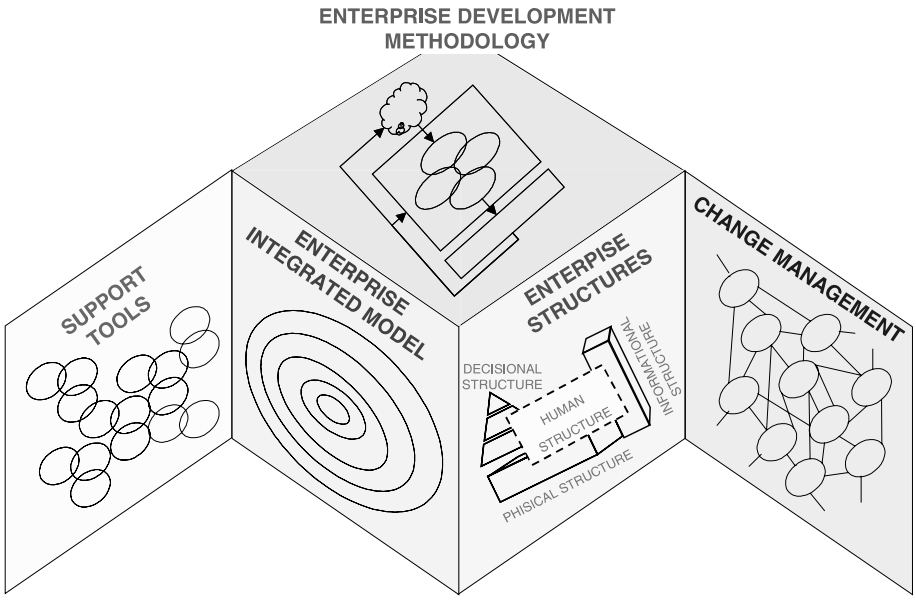

Fig. 1. The five dimensions of the ARDIN Reference Architecture.

guide the construction of an integrated enterprise-system.

2. *Second dimension:* describes how to develop an integrated enterprise model, which aids decision-making during the enterprise design process.
3. *Third dimension:* is based around the formalization of the enterprise implementation process from the model.
4. *Fourth dimension:* identifies a set of support tools, which assist in the process of designing, evaluating, implementing, and controlling the integrated enterprise.
5. *Fifth dimension:* discusses efficient change management, to transform and organize the enterprise resources (including the human resources, which may have different objectives, criteria, formation and culture), in a continuous improvement system.

From a more traditional viewpoint, the architecture can be represented as a unique dimension (the step by step development methodology) and a set of techniques and tools, which give support to each one of the phases of the methodology (the other four dimensions). In this way, the *first dimension* breaks down the project of enterprise integration into four phases: (1) the conceptual phase, which correspond to the identification of business mission, vision, strategy, objectives, etc., (2) the enterprise design phase, using a business process vision, (3) the enterprise implementation phase, and (4) the execution and continuous improvement phase.

Then, the *second dimension* describes the procedure to develop models, which can be used as a support in the enterprise design phase. The *third dimension* is focused on the construction and implementation of the enterprise, on the basis of a model. For example, how to implement an information integrated infrastructure, how to define and organize human resources, how to identify, select and install the physical and technological resources, etc. The *fourth dimension* presents a set of tools (based mainly on information technologies, like case tools, simulation programs, performance measurement systems, etc.) which are applied in the conceptual, design and execution phase. Finally, the *fifth dimension* shows how the enterprise must involve itself in a continuous improvement process to evolve in accordance with its present and future necessities.

4. Extension of the ARDIN architecture for the VE integration

ARDIN architecture has been very useful in applications for a single-enterprise. However, it had to be improved to support the new requirements that appear in the virtual enterprise integration (see Table 2). The rest of this paper shows the modifications made to the ARDIN Reference Architecture to help in the design and management of an efficient and flexible VE.

4.1. Enterprise level

The Methodology for Enterprise Integration (first dimension of the ARDIN architecture) has been extended (1) to describe the whole life cycle of a VE and (2) to develop the appropriate Virtual Enterprise Integration Program. Along with the methodology the Guides for Change Management in Virtual Enterprise Integration Projects (fifth dimension of the ARDIN

Table 2
ARDIN deficiencies to account for design and management of a VE

New requirements to consider in the VE integration (Klueber et al., 2000)	ARDIN deficiencies
Enterprise level: Co-operation should be promoted between all the companies involved in the VE, establishing the required tools and mechanisms for its organization, co-ordination and control. In addition, the VE goals (mission, vision and strategy) must be consistent with each enterprise goals and they must be also coherent with their culture (politics and values) and their structures (commercial, design, production, human resources, etc.)	The enterprise Life Cycle and Life History, the Methodology for the Enterprise Integration Program and the Guides for Change Management of the ARDIN architecture are orientated towards single-enterprises. For that reason • They do not pick up on specific aspects of the VE such as the transactions among the potential virtual partners, or the system of commitments, objectives, goals and plans of the VE • They do not identify the possibilities for improved comepetitivity through co-operation and the sharing of information and resources with other members of the chain • They do not consider the cultural changes necessary in order to achieve the participation and co-operation of the enterprise and its employees in a bigger structure such as the VE • They do not resolve the problems of how to unite the strategy, objectives, plans of action and performance indicators of the VE with those of the component companies
Process level: Once the strategy goals have been defined, the way to achieve these goals through the company business processes must be designed. The adoption of Best Working Practices in the Cross-organizational Business Processes, which break cultural barriers and secure the right exchange of information, is vital if profit is to be taken from the advantages of the VE	The reference models are orientated towards internal processes and have been realized independently for each company in the chain. For this reason they do not present clearly the flow of information and materials within the VE and do not reflect the possibilities of improving efficiency through business co-operation At the same time the existing models identify activities, decisions, resources and information but do not pick up on complementary aspects such as the role played by human resources and the knowledge of individuals
Technological level: It is necessary to develop a technological infrastructure combining the different information and communication technologies, and to develop the required software to automate the information flow of the inter-enterprise processes	The information integrated infrastructure of ARDIN architecture is not designed to solve the problem of the integration of information between different companies in an e-business environment (for example variability in data format, data validity, exchange and the way of sharing them, security mechanisms, etc.)

architecture) have been defined. They (1) take into consideration the organizations cultural values, professional skills, etc. which are needed to join in the VE and they (2) use support documentation that let them measure the integration level of the different enterprises involved in the virtual chain. In addition, the methodology will lead to a Performance Measurement System (PMS) for VE (fourth dimension of the ARDIN architecture).

4.1.1. Methodology for virtual enterprise integration

The first step in the extension of the methodology has been to analyze the Life Cycle and the Life History of a Virtual Enterprise, from the transactions among the potential virtual partners, or the system of commitments, objectives, goals and plans of the VE, as a part of the strategic management activity, until the design and implementation and execution of the business processes. The life cycle of a VE can be represented as a sequence of steps organized in five phases: creation/configuration (strategic planning), design and implementation, execution and continuous improvement, and dissolution (see Table 3).

The Methodology for the Virtual Enterprise Integration Program that is proposed is based on the above VE life cycle. From a practical point of view, it can be summarized as follows (see Fig. 2):

1. Definition of the conceptual aspects of the VE: search for partners, tender formation, negotiation/agreements, contract awarding and management, definition of the VE, mission, vision and values, VE strategy, objectives and general policies.
2. Definition (re-definition) of the conceptual aspects of every-single-enterprise: the mission, vision, strategy, politics and enterprise values.

These two activities are related to each other, but it is not possible to establish clearly which should be first as this depends on the type of VE. For example, if within the VE there is one, which is more powerful than all the rest, this one will tend to impose a strategy that will help its objectives. As a result, the other companies will have to adapt their objectives (and therefore their business processes) in order to fulfill those of the dominant company. On the other hand, if power is more evenly spread, it will be the local objectives of the individual companies that will define those of the VE for the benefit of all in the value chain.

3. Design (re-design) of the new process map (cross-organizational business processes and internal processes

Table 3
Phases of the virtual enterprise life cycle

Phases	Activities	Sub-activities
Creation/configuration	• Search for partners • Tender formation • Negotiation/agreements • Contract awarding and management • Virtual enterprise strategy • Partners strategy	• Definition of the VE • Mission, vision and values • Objectives and strategies • General policies
Design and implementation	• Definition of the cross-organizational business processes • Design of the integrated management system • Virtual enterprise implementation program	• Decision, resources, function and information design • Evaluation of the dynamic behavior • Information and communication infrastructure
Execution and continuous improvement	• New objectives of the virtual company or new requirements of the cross-organizational business processes	• Performance measurement • Change management • Actions plans
Dissolution	• Recycle and disposal	• Evaluation • Learned lessons

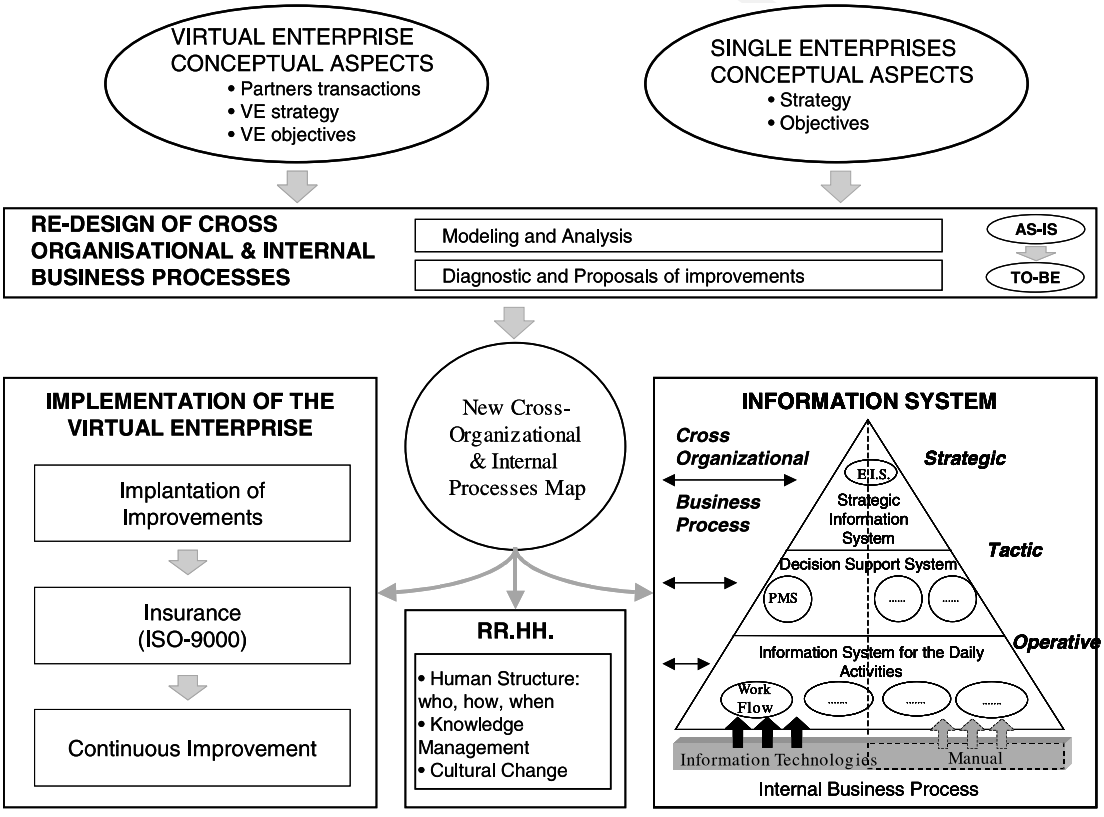

Fig. 2. Enterprise Integration Program.

that are affected by changes) according to the previous defined concepts.

To define the processes map, the actual situation (the AS-IS) has to be analyzed and the new enterprise processes (TO-BE) must be designed. Some authors say that in a virtual enterprise integration project, the AS-IS should be ignored, so as not to retain old obstacles and that the effort should be focused on the design of an ideal TO-BE. However, our experience shows that the actual resources (human and technological) as well as the culture and company psychology are a big constraint. Therefore, for defining the TO-BE processes, the AS-IS has to be understood and the best available solution has to be chosen, thus avoiding a situation based on ideals only.

As a result of this work, the way a VE operates may radically change. These changes may stem from defining new processes or greatly improving already existing ones. Moreover, a large number of small improvements can be identified mainly due to the elimination of activities or carrying them out in parallel, reassigning resources or improving information supply. This phase of the methodology could be associated to a re-engineering project if great changes based on information technologies have been identified. If small changes are obtained, it may be associated to a continual improvement project. These improvement approaches are clearly complimentary and not at all exclusive (Kelada, 1996).

4. *Implementation:* three steps should be taken:
   - To sort the priority of short, medium and long-term improvement projects obtained as a consequence of the new process map and to implant improvement projects of highest priority. Communication and training play an important role in this process of change, which affects inter-company relations and changes the traditional work practices between companies.
   - To establish a quality control and assure method, in order to ensure that the desired changes have been properly implanted.
   - To design a continuous improvement system to implant the medium and long-term improvement projects and to define new goals or changes in the enterprises or processes to adjust the VE to the environmental changes. For example, although part of the network will remain relatively stable, non-strategic nodes can be dynamically added/removed according to the current/future business opportunities and the current/future state of each cross-organizational business process.
5. To organize and to manage human resources according to the process map. All the workers and managers have to know what their activities and responsibilities are, not only for each enterprise management but also for the management system among enterprises (who, what, where, how and when). This obliges to create a less departmentalized company with a less hierarchical structure and orientated more towards processes management. At the same time it is necessary to be able to identify, extract, process, store and distribute (with the help of a computer system) the knowledge, which will enable all the component companies to share the experience and skills of the human resources.
6. To extend the information system (and the technological infrastructure) to support the process map of the VE, considering the different decision levels and the support technology.

4.1.2. Guides for change management in virtual enterprise integration projects

A virtual enterprise integration project implies technological and management changes as well as cultural changes. The organizational culture has to be changed so that new forms of co-operation and relations can be established between the company and its employees, in a bigger structure such as the VE. What is attempted is that the enterprise does not regard its supplier as an enterprise from which it is only necessary to get cheaper prices, but also as part of its own structure to cooperate and share information and resources with. In this way a real common profit is obtained and it is easier to achieve a competitive advantage over the rest of the market (Cuesta, 1999).

The guides for change management developed within the ARDIN architecture include templates for an easier adaptation and customization of the methodology and the reference models to specific companies. Some of the forms produced are for:

- Evaluation of resistance to change, identifying catalyses or inhibitors in the adoption of new technologies and management models for the VE.
- Identification of tasks carried out departments and people.
- Detection of organization or technology inadequacies with regard to the reference models.
- Analysis of the role of human resources in the VE.
- Definition of the precise contents of the circulating documents.
- Evaluation of the technology required to carry out the activities.
- Measurement of the performance of the VE.

4.1.3. Performance measurement system for virtual enterprise

To secure the successful integration of the VE it is very useful to make use of a PMS that allows you to translate the VE mission and strategies into a set of interrelated indicators. This set of indicators can be employed as the foundation of an integrated and iterative strategic management system of the VE. It enables the VE to:

- Clarify and update strategy.
- Communicate strategy throughout the different companies.
- Align unit and individual goals with the VE strategy.
- Link objectives to long-term targets and annual budgets.
- Conduct periodic performance reviews to learn about and improve strategy.

With this PMS at the kernel of the management system, a VE can monitor short-term results from dif-

ferent perspectives (financial, customer, internal business processes, quality, environmental and learning and growth) and evaluate strategy in the light of recent performance.

In order to build the PMS it is necessary to follow a sequence of hierarchical deployment. The first step begins at the strategic level where the managers of the different enterprises design the VE as a whole. Then, they go through an iterative cycle that contains the following activities:

- To define VE strategic objectives.
- To translate VE strategic objectives to actions plans.
- To select strategic cause-effect indicators and to establish their relations.

The next step is to transfer the organization's high level strategic objectives and measures that identify the performance and the degree of integration with the VE. The identification and organization of the objectives and the measures to obtain them, depends on the type of VE, but at least the following aspects should be analyzed and evaluated.

- Mechanisms for organization and co-ordination of all the companies involved in the VE, in order to (1) develop specific plans of action of joint activities and (2) identify organizational changes which will promote efficient co-ordination amongst the companies and the exchange of information between them.
- Working practices in the inter-enterprise critical processes.
- Technological platform, which permits the atomization of the information flow of the inter-enterprise processes.
- Communication techniques oriented to reduce the cultural and organizational differences between the companies.
- Relations among people of the different companies in order to share information, exchange technology and participate in working groups.

Once the objectives and performance indicators of the management of the VE have been established, it is necessary to apply the previous steps to all the companies of which the VE is composed. The objectives and performance indicators to be defined depend on the nature of each company but should be coherent with those previously established for the management of the VE. So, the PMS will give managers a way of ensuring that all levels of the VE understand the long-term strategy and that all, individual enterprises, departmental and local objectives are aligned with it.

The last point to be considered concerns the analysis of results and to update the strategic or business process of the VE and the private company, through reviews. The PMS, therefore, does not have to be considered as a way of producing a set of indicators, but rather as a mechanism for improving the efficiency and productivity of the VE.

4.2. Process level

The use of reference models which describe the best practice in the intern processes (purchases, production, storage, design, etc.) as well as in the cross-organizational processes is essential to help in the virtual enterprise integration. So, Reference Models (second dimension of the ARDIN architecture) have been developed with the best work practices in Virtual Enterprises of different sectors (Chalmeta, 2000). In these models both the company internal processes like purchases, production, storage, dealing, finances, etc. and the external processes like the relationships with suppliers, customers, transport companies, public administrations, etc. are considered. The models show the several activities included in every process, the decisions that are taken, the information flow, the technology used, the control mechanism of the workflow and the knowledge of the human resources involved in the processes. These reference models let you contrast the way of working of different enterprises that want to constitute a VE, in order to detect shortcomings and improvement opportunities.

The reference models decrease the complexity in the design process of a VE, whose design decisions are taken by different groups with different background and objectives. The use of models allows understanding, analyzing and evaluating the impact of the decisions on the system performance before its construction and during its execution. These models may be used for:

- Communication of design decisions among involved parties.
- Decision support (e.g. for the analysis of current operation to identify the need for change).
- Education and training of personnel, and in general explicit representation of company knowledge.

The difficulty in the generation of reference models of the VE does not lie in languages of modeling, which are basically the same ones as in the modeling of one enterprise, but in reflecting in the models the *possibilities of improving the efficiency through business co-operation*.

The virtual chain management business process is an example. It is the set of activities that take place (in each one of the enterprises that are part of the VE) to deliver and/or make a product and/or service required by a final customer. Co-operation possibilities can be established in two levels:

- *Integration of the planning and management system.* This involves the co-ordination of production and services planning in all the companies included in the logistic chain, using forecasted sales to end-users. The benefit for this area will be an increase in the reliability of the different planning levels (aggregate, programming and sequencing) that will bring a decrease in inventories and costs, a better inventory control and, in summary, an improved customer service.
- *Integration of the operating process for order management, using electronic commerce technologies.* Benefits for this area will be a decrease in cost and time in customer order collection and processing and in issue of orders to providers, as well as in the production and handling of the remaining commercial documentation.

In order to develop the Reference Model of a Virtual Enterprise, different modeling languages can be used. Inside the ARDIN architecture a hierarchic approach is adopted. In a first approximation, IDEF0 (CAM-I: Consortium for Advanced Manufacturing-International, 1981) and GRAI nets (Doumeingts, 1992) are used to represent, in a high level, the different activities and decisions within the different business processes. Then an object-oriented reference model using the Unified Modeling Language (UML) and agents is developed to describe the VE business process and the computer information system in more detail. To develop a flexible model for the control and management of the workflow, the Workflow Management Coalition (WMC) (Hollingsworth, 1995) techniques are applied. Finally, for the definition of the roles played by the human resources, and to describe the knowledge and skills required to execute the different activities in the VE, the integrated methodology of (Nissen et al., 2000) is a good option.

4.3. Technological level

A Technological Infrastructure has been designed (third dimension of the ARDIN architecture) which considers the new information and communication technologies for supporting the smart integration of the VE. The technological infrastructure automates the information traffic in the VE for supporting the cross-organizational business process.

Next, the analysis of the technological infrastructure of the VE is introduced from a participating enterprise internal point of view (see Fig. 3).

The information which is handled within the VE is very big and is going to increase due to the rapid advance of the new computer technologies. But the big problem that enterprises have to face is not only the handling of large amounts of information, but also the control of certain characteristics of that information such as the variability in data format, the validity of that data, their exchange and the way of sharing them, etc. All these factors are especially important in the integration of the information system of the VE.

Companies usually focus on the integration of organized data, not only those that are part of the transactional system (ERP), but also those that are part of the decision system (Management and Strategic information systems). However, the new business requirements make it necessary to include not organized data like web, files systems, call centers, e-mail, office automation systems, etc. as this kind of information is arriving more and more frequently at the company and it can be very

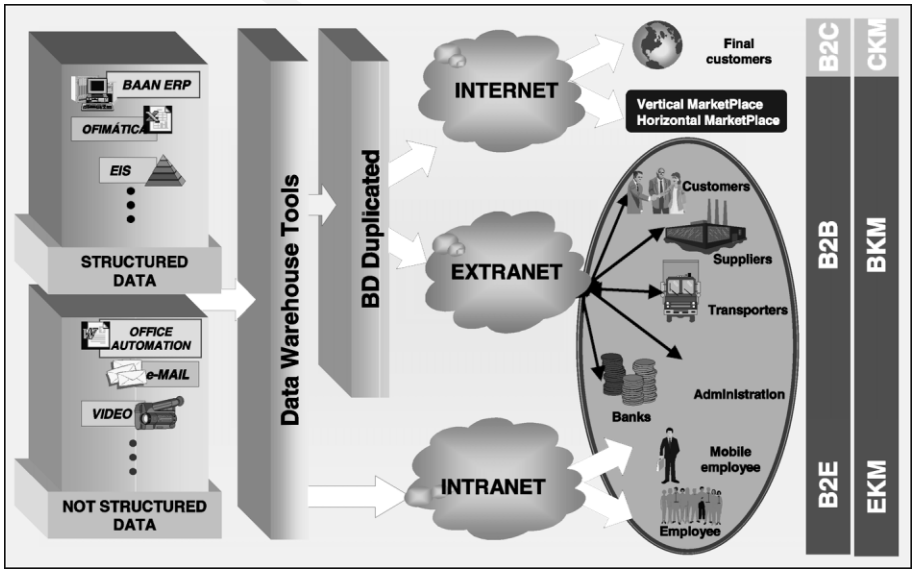

Fig. 3. Technological infrastructure for VE, from a single-enterprise point of view.

valuable for its management. Therefore, the VE technological structure must consider Date Warehouse and OLAP (On-Line Analytical Processing) Technology (Chaudhuri and Dayal, 1997) which allow the integration of organized and non-organized data in the enterprise information system. Next, the features of the technological level are shown in more detail, distinguishing between the communication infrastructure and the possibilities of use of the information.

4.3.1. Communication infrastructure

Once the company has been able to integrate the organized and non-organized data, it can (1) turn these data into useful information for all the employees in the organization and (2) share and exchange the resulting information with the other members of the VE in a way that it has an effect on the common benefit. From the point of view of communications, the physic architecture will be different according to the information addressed: the company employees or other companies participating in the VE.

4.3.1.1. Information addressed to other participating companies. Firstly, starting from the information already integrated, it is necessary to make a copy of the database in order to achieve two objectives. On the one hand, to provide information access to the rest of the companies that participate in the VE. On the other hand, to assure the company which shares information that the integrity of its data will be kept. Starting from the information stored in the copied database and by means of a distributed information system, the information can be shared after establishing the right security mechanisms (Public Key Infrastructure systems, intelligent targets, digital certification, etc.) (Ghosh, 1998) through two communication channels:

(a) The use of *Internet* as a means to reach those places which the company cannot have access to with its own communication network. In the case of the VE, it will be used in a way that will enable the company to get in touch with the final clients directly and without intermediaries. For this, a web gateway needs to be developed (Camarinha-Matos et al., 2001) combining different technologies as HTML, ASP (Microsoft Active Server Pages), Macromedia Flash, JAVA script; XML (eXtensible Markup Language), and XML-EDI (Electronic Data Interchange), which connects directly with the copied database. This web gateway will have two functions, (1) to make the VE known to its final clients, and (2) to allow the clients to make their orders, their complaints, their consultations, etc. on line.
(b) The construction of an *Extranet* which will establish the connection between the copied database and all the components of the VE (transporters, suppliers, banks, administration, etc.). What is intended is to establish an own and secure communication network which will allow those participating in the VE to share and anticipate information in a way that it can work in an integrated way.

4.3.1.2. Information addressed to the enterprise internal management. On the other hand, information is also internally shared within the company by employees through an Intranet. In this case, to make a copy of the database is not necessary, but the data, organized and not organized ones, must be integrated by means of Data Warehouse Tools.

Thanks to the new communication technologies, this employees' access can take place whether they are physically at work whether they are out it by means of the latest mobile devices. For example, to provide wireless Internet access through a micro-browser installed on the mobile phone. Wireless Application Protocol (WAP) access to electronic commerce services is feasible by introducing a proper gateway that permits the interaction between the GSM/UMTS (Global System for Mobile communication/Universal Mobile Telecommunications System) network with the Data Exchange Server.

4.3.2. Possibilities of using information

The technological infrastructure previously described, is going to make it easier for the company to able to:

- Distribute and exchange with other companies the necessary information for the activities execution and decision making, including in the knowledge and abilities of human resources. Human knowledge can refer to the company employees (EKM, Employment Knowledge Management), other companies (BKM, Business Knowledge Management), and customers (CKM, Customer Knowledge Management).
- Establish a workflow system which allows the automated exchange of information, guaranteeing both the quality of the processes that take place in the company and the security that information flows in the right circuits.
- Establish electronic commerce relationships in three fields: B2C (Business to Consumer), B2B (Business to Business) and B2E (Business to Employment).

In the field of B2C, the company has the chance of sending its products and/or services to the final customer directly and without intermediaries. To achieve it, the company provides a series of interfaces which allow the end-user to acquire a certain product and/or service from home thanks to Internet and through a gateway. This practice, which is common in many companies nowadays, will be only useful if both the information in Internet and the data taken from it are integrated in the

company information system. If the end-user made an order through Internet and then the company needed an employee to introduce that order in its ERP, everything would be useless.

In B2B, the concept of VE becomes more important. On the one hand, the company can do business through Internet by establishing or participating in vertical and horizontal marketplaces. On the other hand, and this is the most important option from the point of view of the VE, the company can establish an Extranet with the different members participating in the VE (customers, transporters, suppliers, administration, banks) in a way that a quick and efficient means to share information is established.

In the field of B2E, the most important aspects in the internal exchange of information among a company employees are: the information integration; and the use of a right technology (WAP, GSM, etc.) which allows the employee to have access to the same information when the employee is within the company as well as when he is physically out of it.

5. Application of ARDIN to virtual enterprises

Different qualitative and quantitative methods were used to define the VE life cycle, to build the methodology and the models, and to design the technological infrastructure. In the first place, the literature related to this line of research was reviewed and the results of different projects related to the integration of virtual enterprises were analyzed, as for example the GlobEMEN project (Global Engineering and Manufacturing in Enterprise Networks) (GlobEMEN web site, 2002), funded by the international Intelligent Manufacturing Systems (IMS) program or the VEGA project (Virtual Enterprises using Groupware tools and distributed architecture) (VEGA web site, 2002). In that way, clear vision and better understanding about the topic was obtained.

After this, information about virtual enterprises was collected by means of the interview and questionnaires to managers of companies of various sectors (Chemical, Construction, Transport, Textile, Consulting, Information Technology) which had the capacity to constitute or participate in a VE. Once this information was put together and processed, a first version of the extended ARDIN architecture was made.

Finally the results were applied to two case studies to (1) validate and document the benefits and lessons learned in the form of a well-understandable business case and (2) improve the initial results by applying to them the conclusions extracted from those results.

The two study cases are one from the tile sector and another from the transport sector. A Virtual Tile Enterprise is a VE composed of enterprises in different sectors that are involved in the life cycle of tile products like tile manufacturers, suppliers, customers, transport companies, dealers, public administrations, financial entities, etc. It is a kind of VE where an organization concentrates the main activities on the value chain of a product or service, named Core Business, and it looks for complementary enterprises to complete the value chain (Hamel and Prahalad, 1995). A Virtual Transport Enterprise is a different kind of VE. In the global market environment, the majority of the transport companies do not have the financial and structural capability to be able to afford the cost of operating direct routes with different origin and destination points. So, in order to satisfy the customer requirements, local transport enterprises must work together through the establishment of co-operative agreements forming a Virtual Transport Enterprise. This is an example of the value-alliance models (Burn and Ash, 2000).

The procedure adopted for the application of the extended ARDIN architecture in the case studies was as follows. First, according to the ARDIN methodology, a broad definition of the principle objectives of the VE were established, beginning with an identification of the business, the mission, vision, values and an outline of client groups and market segments on which each type of the VE was focused.

The next task corresponded to the definition of the strategy of the VE, not in terms of the current situation of the company, but as an opportunity to improve. For this it was necessary to (1) analyze the *strategic problems* which confronted the VE with respect to their competitors, (2) define the main *deficiencies* with respect to the strategic formulation, proposing improvements to determine suitable mechanisms to achieve a co-ordinated and effective strategic planning for the VE and the component companies and (3) establish the *strategic objectives* for the VE.

The definition of the conceptual aspects of the VE is closely related to the conceptual aspects of each individual component company. In the case of the virtual tile enterprise, the manufacturing company occupied a dominant position in the chain and there fore the strategy and vision of this company determined those of the VE, which in turn conditioned the conceptual aspects of the other companies in the chain which had to modify their strategy and objectives. In the case of the transport enterprise, however, where no one company holds a particularly dominant position, the conceptual aspects of the VE were arrived at in a more consensual manner and the objectives of all the component companies being considered.

Once the conceptual aspects had been defined, the cross-organizational and critical internal business process were analyzed (AS-IS) in order to build models which identified their different activities, decisions, information and resources required by them. Then, based

on the Models with the Best Practices and on the Guides for Change Management in Virtual Enterprise Integration Projects a technologic and organization audit was carried out. This audit made it possible to define the various plans of action needed to resolve the strategic problems which had been identified and to achieve the proposed objectives (TO-BE). Finally, the new working models, the new roles for human resources, and their supporting technological infrastructure were installed.

The profits detected after the application of the extended ARDIN architecture by companies which collaborated in the studied cases, are both tangible and intangible. It was only possible to measure tangible benefits in the transport sector as it was only in this sector that it was possible to set up a PMS. So the following quantitative results were obtained from applying the ARDIN architecture to CAVE Logistics, a Spanish virtual transport enterprise composed by 55 small and medium size companies: lead-time reduction: 30%; cost reduction: 25%; productivity increase: 30%; human satisfaction: 20%; new customers: 80%; no quality cost reduction: 20%.

On the other hand, intangible results in both case studies are:

- The project has created a cultural change in the companies daily operation, orienting them towards a higher final customer satisfaction, which is key for increasing their competitivity. In this way the company which sells the product (tiles) or which contracts the transport services are not the only ones thinking of the needs of the client at the end of the line. For example, in the case of the tile sector case study, the manufacturer designs the tiles together with the supplier of the enamels, taking into account the demands of the final consumers of the product as defined by the distributors. In this way it can be ensured that the suitable raw materials to manufacture new products will exist and that the new products will find an outlet on the market.
- The enterprises are evolved towards a more dynamic environment, actually promoting a re-engineering of their internal structures. In this sense it was significant that in order to improve competitivity through co-operation and sharing information and resources with other members in the chain, these companies had to change from a heavily hierarchical, departmentalized structure to processes management in which they had to give greater freedom of action to their employees.
- SME's customers enjoy more flexible and customized services. Customers' request is satisfied in the most economical and convenient way exploiting the advantages of an efficient VE.
- The technological infrastructure makes it possible to optimize the flows of information in the virtual chain, making easy the improvements in productivity and the efficiency in the development of activities.

6. Conclusions

There are different approaches to help in the integration of an enterprise, but the right methodologies and techniques in order to make it easier to integrate and co-ordinate all elements (enterprises, technologies, organization systems, human resources, etc.) involved in the life cycle of a product or service, have not been completely developed till now.

In this article the extensions made to the ARDIN architecture to adapt it to the necessities of integration of the VE have been introduced. Mainly they are a methodology for VE integration, a group of reference models with the best work practices and a technological infrastructure.

The extension of the ARDIN architecture will make it possible to increase the enterprise competitivity, increasing the value of the products or services that are offered through:

(1) The reorganization of the VE structure, providing tools that let the new organizations a dynamic entrance and exit from the value chain.
(2) The flexible and pro-active co-operation between the organizations involved in the value chain of the product or service in order to obtain an efficient and quick response/anticipation to the market changes.
(3) The design of high performance internal and cross-organizational business process, supported by the new information technologies (e-commerce, knowledge management, workflow, etc.).

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References

Amice, C., 1993. CIM-OSA: Open System Architecture for CIM. Springer-Verlag, Berlin.

Bernus, P., Nemes, L., Williams, T.J., 1996. Architectures for Enterprise Integration. Chapman and Hall, London.

Bernus, P., Nemes, L., 1999. Organisational design: dynamically creating and sustaining integrated virtual enterprises. In: Chen, H.-F., Cheng, D.-Z., Zhang, J.-F. (Eds.), Proc IFAC World Congress, Vol. A. Elsevier, London.

Burkel, J., 1991. Applying CIM for competitive advantage. In: Burkel, J. (Ed.), Proceedings of Autofact'91, Chicago.

Burn, J.M., Ash, C., 2000. Managing Knowledge for Strategic Advantage in the Virtual Organization, Edith Cowan University, Australia.

CAM-I: Consortium for Advanced Manufacturing-International, 1981. Architect's Manual, ICAM Definition Method, "IDEF0", ICAM Library Catalog, Poole (G.B), DR-80-ATCP-01.

Camarinha-Matos, L.M., Afsarmanesh, H., Osório, A.L., 2001. Flexibility and safety in a web-based infrastructure for virtual enterprises. International Journal of Computer Integrated Manufacturing 14 (1), 66–82.

Chalmeta, R., 2000. Virtual transport enterprise integration. Journal of Integrated Design and Process Science 4 (4), 45–56.

Chalmeta, R., Campos, C., Grangel, R., 2001. References architectures for enterprise integration. Journal of Systems and Software 57 (3), 175–191.

Chaudhuri, S., Dayal, U., 1997. An Overview of Data Warehousing and OLAP Technology. SIGMOD Record 26 (1), pp. 65–74.

Cuesta, F., 1999. La empresa virtual. McGraw-Hill, Madrid.

Doumeingts, G., 1992. GRAI-GIM Integrated Methodology, A methodology for Designing CIM Systems, Version 1.0. LAP/GRAI, University of Bordeaux, France.

Ghosh, A.K., 1998. E-commerce Security Weak Links, Best Defenses. John Wiley, New York.

GlobEMEN web site, 2002. http://cic.vtt.fi/projects/globemen/public.html.

Hamel, G., Prahalad, C.K., 1995. Compitiendo por el futuro: estrategia crucial para crear los mercados del mañana. Editorial Ariel, Barcelona.

Hollingsworth, D., 1995. Workflow Management Coalition The Workflow Reference Model. http://www.wfmc.org.

Kelada, J.N., 1996. Integrating Reengineering with Total Quality, ASQC Quality Press Cop. Milwaukee, Wisconsin.

Klueber, R., Alt, R., Österle, H., 2000. Implementing virtual organizing in business networks: a method of inter-business networking. In: Malhotra, Y. (Ed.), Knowledge Management and Virtual Organizations. Idea Group Publishing, London.

Nissen, M., Kamel, M., Sengupta, K., 2000. Integrated analysis and design of knowledge systems processes. In: Malhotra, Y. (Ed.), Knowledge Management and Virtual Organizations. Idea Group Publishing, London.

Pantakar, K., 1995. Enterprise integration modeling: a review of theory and practice. International Journal of Computer Integrated Manufacturing 8 (1).

VEGA web site, 2002. http://cic.cstb.fr/ILC/ecprojec/vega/descript.htm.

Williams, T., 1993. The purdue enterprise reference architecture. In: Proceedings of the Workshop on Design of Information Infrastructure Systems for Manufacturing. Elsevier Science, Tokyo, Japan.

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