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The Journal of Systems and Software 57 (2001) 175–191

The Journal of Systems and Software

www.elsevier.com/locate/jss

References architectures for enterprise integration

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Received 1 August 1999; received in revised form 1 December 1999; accepted 1 June 2000

Abstract

The dynamic and competitive enterprise environment requires enterprises to ensure the highest profit from their resources, integrating them to work together in obtaining the enterprises objectives. The project of design and implementation of an Integrating Enterprise System, is an extremely complex project that involves different technological, human and organisational elements. For this purpose several different reference architectures (RA) have been proposed. However, this area of research is not yet totally satisfactory because these methods may still be improved. It is necessary to adapt the different techniques to the concrete needs of each type of enterprise activity. In addition, new methods enabling the integration of several enterprises (called virtual enterprises) must be developed and their use must be popularized through examples and application experiences. This paper shows the results of the research project in RA for enterprise integration of the IRIS group from the University Jaume I of Castellón. Mainly, it is a framework consisting of a step by step methodology, reference models and a set of supporting tools, which will allow the creation of an Integrated Enterprise. Some of the results obtained from the applications in different enterprises are also shown.

Keywords: Enterprise integration; Reference architectures; Enterprise models; Integrated information systems

1. The new enterprise action framework

Changes in the world economic environment, along with to the development of new technologies, especially in the information field, configure a 'new action framework' for the enterprise. This is one in which we go from old endeavour associated with positions in local markets to a 'maximally competitive' global market. This forces us to constantly modify the culture, the mode of operating and the internal organization structures of the company, in order to compete and survive in this environment.

The new highly dynamic action framework is characterized mainly by four 'external strengths (see Fig. 1) that directly affect the competitiveness of the enterprise (Vernadat, 1994):

1. the 'world-wide extension of the market', which forces the enterprise to *extend* and *enlarge* its action radius, and at the same time introduces *new competitors* in its traditional influence area (Brown and Sackett, 1994);
2. the increasing 'client requirements' which forces the enterprises to manufacture with a higher emphasis on quality; on customizing demand; on offering a better service and on diminishing costs;
3. the 'technological development', which provides tremendous opportunities to improve the enterprises' performance;
4. the 'environmental impact' which will result in the short and medium term in *restrictions* imposed by law, which will force the enterprises to modify their operating systems.

2. The need for enterprise integration

To maintain and improve their 'competitiveness' while reacting to the fast 'changes' that take place in the opportunities and needs of the market, enterprises must adopt a form of organization and operations that will allow them to obtain the 'maximum benefit' from their resources.

Recently several approaches oriented toward the improvement of the enterprise's competitiveness have appeared. (McCarty, 1993) lists the main 'tendencies' which emphasize total quality management, process

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PII: S0164-1212(01)00008-5

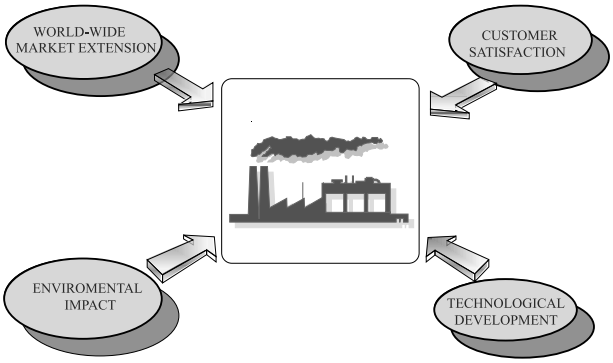

Fig. 1. The four external strengths that affect the enterprise competitiveness.

re-engineering, collaboration between enterprises, virtual enterprise, improvement of the availability of information, flexibility, and the integration of clients and suppliers.

These new tendencies and innovations in the fields of management and technology have almost always been handled in the enterprises in an isolated and uncoordinated way. Thus the large promised 'improvement expectations have not been accomplished'.

Therefore, in order to achieve all the possibilities that these new and better methods and tools offer, an enterprise must 'efficiently manage' all of its elements, 'aligning' and 'integrating' them in order to improve the ability to work together in a 'continuous improvement process' toward the accomplishment of the objectives and the strategy of the enterprise.

The necessity for 'integration in the enterprise' has been developed by many different authors like (Amice, 1993) and (Neuscheler, 1994) amongst others. One of the better definitions is that of (Lawrence and Lorsch, 1968), who defines integration as "the quality of the 'collaboration' that exists between departments (marketing, finances, manufacturing, store, etc.) in order to 'satisfy' the environmental requests ... and the processes, methods and resources thanks to which it is satisfied". The work developed by (Petrie, 1992), is also interesting, as it analyzes and justifies integration as the key variable to support the new requirements of the market.

In this way, the conclusions of the work carried out by the National Research Council of USA, when asked by NASA, on the 'impact that the efforts toward integration' were producing in concrete American enterprises like Westinghouse or General Motors (National Research Council, 1986), allows us to determine that the benefits of integration are of two types: 'strategic benefits' (which give a competitive advantage to the enterprise, establishing the best business objectives and adequate means to reach them) and 'tangible and quantitative benefits'.

These latter result in: (1) decreasing the delivery times of the products (30–60%), (2) product design time (20–50%), (3) product design cost (15–30%), (4) manufacturing mean time (50–70%), (5) space (25–40%), (6) inventory cost of the raw materials (30–60%), (7) of the product being produced (60–80%) and of (8) final products (40–50%), (9) direct manpower cost (20–35%) and (10) indirect manpower cost (30–35%), (11) quality cost (25–40%), and (12) throughput increasing (40–70%).

3. Evolution in the integration concept

The 'enterprise integration' concept, as it is posed in this paper, is a new concept that comes out of the evolution of the influences of different focuses, such as *business re-engineering*, *total quality management*, *integration of customers and suppliers*, *ERP's* etc.

The first approach toward industry integration was focused mainly on the technological aspects, solving the connection problems between different devices and the exchange of information between computer applications.

However, in the new action framework of the enterprise, it is necessary to adopt a more global focus, in agreement with the definition of 'enterprise integration', which should cover the whole enterprise and adopt an organizational focus, more than a technological one.

Nowadays, enterprise integration is applied to any type of enterprise (industrial, service, transport, businesses, etc.), and one of the main current lines of research in this field is the integration of enterprises from different sectors that play a role in the lifecycle of a product or service (virtual enterprises).

4. Enterprise integration and information systems

It is important to clarify in this point the difference between an integrated enterprise and an integrated information system. Enterprise integration, as has been defined earlier, is a focus on the enterprise's organization and functioning which includes activities, decisions, resources and information flow in a joint system in such a way that everything behaves in a 'co-ordinated' manner in order to satisfy global objectives an improve performance.

To achieve this goal it is necessary to adopt an innovating viewpoint regarding information. This should be considered a fundamental mechanism for the total integration of the enterprise's engineering and management functions.

From this approach, a fundamental objective for any enterprise integration project is the need to create a 'global information infrastructure' supported by the new

information technologies. This should be an infrastructure focused on flexibility and efficiency in its functioning. It should (1) carry out efficient information processing offering the correct information at the appropriate time; (2) allow for the co-operation between the enterprise's subsystems and its external elements; (3) cover up the heterogeneity of physical resources and information applications and (4) be able to respond to changes in the enterprise's way of functioning and the evolution of support technologies (Mayer and Painter, 1991).

Nevertheless, and integrated information system does not assume that enterprise activity has been integrated. Even though the incompatibilities that impede physical communication and exchange of data and information have been overcome, enterprise decisions may still be made in order to optimize particular and contradictory objectives. Only when the information is used within the 'co-operative integrated management framework in order to 'co-ordinate' activities and decisions towards strategic objectives ensuring communication and collaboration among groups and individuals in the firm, will the information behave as a valid mechanism for 'total enterprise integration'.

To build a computerized integrated information system capable of providing correct information wherever it may be needed, incompatibilities appearing on both, the physical level between different communication networks and protocols and the logic level between databases and software, must be overcome.

Of these two elements, software proves to be the most restricting. There are two alternatives for obtaining a software adapted to a particular enterprise's needs: to develop a customized software or to use a standard solution. Each alternative has its advantages and drawbacks.

Theoretically, a customized development will always be closer to the enterprise's particular needs. Even so, cost and time are considerable. Moreover, inevitable changes in the system (both physical and logical) may require an almost complete overhaul of applications thereby wasting a large part of previous investments.

The other option is to use a manufacturer developed standard solution. This solution is parameterized to the enterprise's needs trying to limit changes to the original. In this way, it is ensured that future versions and improvements that the manufacturer may include in the software can be adapted to the enterprise. Two types of standard solution applications can be distinguished, namely sectorial software and ERP systems.

Sectorial software is a set of computer applications developed in order to fulfill the particular needs of a sector. The software enterprise tends to be a small or middle-sized computer firm geographically situated near a cluster of enterprises belonging to the same sector and which posses a profound knowledge of its needs. As a result, the software is well adapted to this kind of enterprise thus implantation time is short and, due to scaled economies, the cost is not excessively high. Its main disadvantage is the size of the software enterprise which makes it unable to possess enough resources to extend the product to all areas of the enterprise and to ensure technological updating. These closed systems are very specific, of limited flexibility and do not deal with information as an enterprise resource. This makes total enterprise integration and reaping its subsequent benefits impossible to obtain.

The other option are the enterprise resource planning (ERP) systems. These are systems which were first developed to cover the needs of one sector. However, thanks to widespread ERP use, the developers have turned into large multinational enterprises and their functions have been extended to include a large number of enterprise activities. Examples of these are SAP, BAAN, ROSS, Peoplesoft, etc. (See the Gartner group comparative matrix). Its strengths include (1) size and stability of the software enterprise, which guarantees constant technological updating; (2) the database and computer applications are integrated which enables information to be shared; (3) it involves a large part of the enterprise and (4) some ERPs have process modeling and documentation tools, which in some way, allow to join the organization, the software and quality assurance.

Nevertheless, the time and the cost of every implantation are too high, especially when modifications to the standard application are necessary. To avoid this, manufacturers tend to develop sectorial maps. Basically, this consists of adding a layer over the standard software (without modifying the kernel of the ERP) closer to the needs of a sector. In this way, there will be far fewer modifications when time comes to implant it into a particular enterprise. Nevertheless, the function of even the most widespread and advanced ERP systems is not the same and this should be taken into account. This is due to the fact that having been initially developed for a particular sector, they are always better-prepared for this sector and less-prepared for other sectors than their competitors. The current trend is to widen their performance realm to cover not only operative and management type processes but also to offer information for strategic decision-making and connection among enterprises, thus giving solutions for e-business (Fig. 2).

From the standpoint of enterprise integration, ERP systems seem to be the best solution currently. Appropriate software enables the enterprise to improve efficiency, but at the same time, it forces people to work in a certain way. This is one of the main reasons of delays in software implementations. The managers of the enterprise think that software is like a machine, which you buy and begin to work quickly. They do not see software as a complex element which affects the entire organiza-

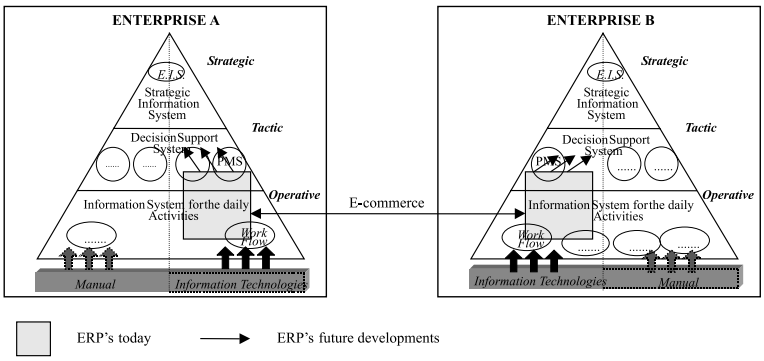

Fig. 2. Mapping the ERP's position in the enterprise.

tion and functioning and which interacts with a large part of the firm's human resources.

5. Architectures and reference models

To carry out the project of master planning and implementation of an 'integrated enterprise system' is an extremely complex process which involves different technological, human and organizational elements. In order to make the study of existing systems and the design of new more advanced systems easier by reducing the complexity level, it is necessary to establish a step by step development 'methodology' and to 'formalize' the creative process in each phase of the whole project (Pantakar, 1995).

However, the management of an enterprise integration project is usually only *informal and unstructured* using heuristic methods derived from past experience. These techniques are insufficient which increases the necessary time to develop the system and produce suboptimal solutions.

As a result, more and more frequently, people are looking for more formal tools and more robust proceedings derived from the 'analysis based on models' which would cover all the enterprise and would allow one to show the relationships between the several functional areas. This type of technique enables us to formulate the enterprise strategy, analyzing and evaluating the global impact it produces in the enterprises beyond the limits imposed by the functional areas (CAM-I, 1981). Another characteristic of this kind of models is that they are 'open'. That is, they describe the relationships between the enterprise and the external world, including its requirements and constraints, and shows the 'dynamic dependencies' between the activities.

Crossing from this theoretical frontier to the practical one implies the generation of a procedure by which these *formal* methods can be used in the enterprise (Williams, 1989). In this way, several efforts in the development of (1) enterprise models and (2) enterprises analysis and design methodologies are being carried out (Chalmeta, 1997b). This results are usually called reference architectures.

A reference architectures (AR) is a *framework which guides 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).

The architecture must guide the development and application of all of the disciplines involved in the enterprise integration project, systematically modeling all parts of the life cycle of the enterprise. This means the states of definition, specification, detailed design, physical implementation or construction and maintenance, till its obsolescence. All the activities in the enterprise integration project must have their place in the RA and the enterprise development program must be detailed step by step.

Several such architectures have already been proposed by 'International Research and Development groups' (see Fig. 3). Based on a review made of the different existing proposals, whose results are presented in (Chalmeta, 1997b), 'two types of architectures' have been identified with different objectives. These are the ones directed toward the development of 'integrated information systems' and the ones which cover the 'whole enterprise integration project'. The latter are more oriented toward the problem this paper is focused.

The 'RA for the integration of information' have the objective of developing an integrated information infrastructure that communicates and coordinates the different technological devices that generate, process, distribute, and supply information. One of the most wellknown is the ARIS Architecture generated by the Institut fuer Wirtschaftsinformatik of the Universitaet des Saarlandes (Germany) (Strunz, 1990).

The 'RA for enterprise integration' are oriented toward the integration of the whole organization, considering not only the technological aspects of the system, but also the economic, social and human ones. Among the most wellknown ones are:

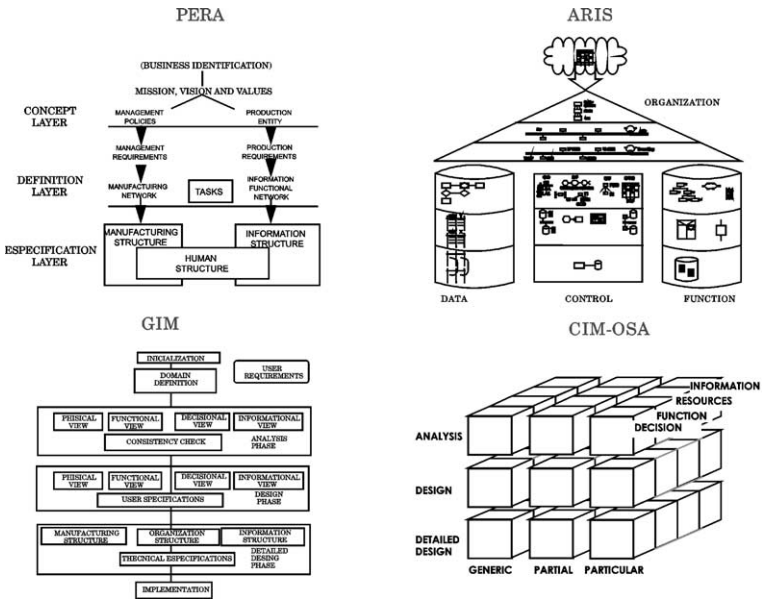

Fig. 3. Main RA (in PERA it is only show part of the enterprise life cycle).

- CIM-OSA (*open systems architecture*). Architecture presented in the ESPRIT programs of the European Union (number 688, 2422 and 5288), by the AMICE Consortium (Amice, 1991).
- GIM (*Grai integrated methodology*). Architecture derived from the work carried out by several projects subsidized by the ESPRIT program of the European Union like IMPACS (number 2338) by the GRAI Laboratory of Bordeaux University, France (Doumeingts et al., 1992).
- PERA Architecture developed by 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' *project* (International Federation Automatic Control International Federation Information Processing) (Bernus et al., 1996). This project had a first objective (1991–1993) which consisted of the selection of an architecture that would describe and present all the necessary activities to establish, carry out and complete an enterprise integration program for any kind of enterprise.

Due to political factors, it has been impossible for the members of this group to select only one architecture

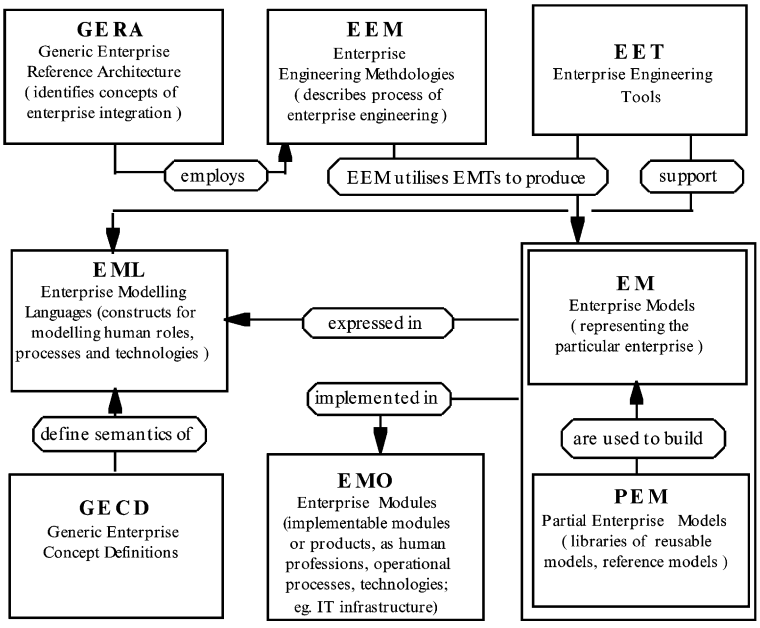

Fig. 4. GERAM components.

that could be considered by everybody as the best one (Williams and Li, 1995). However, thanks to the wide study carried out in this work in the second period of three years of the project (1994–1996) the requirements and components, which such a RA has to fulfill in order to be considered complete, have been defined. These requirements and components are synthesized in generalized enterprise RA and methodology (GERAM), see Fig. 4) and are being studied by the International Standard Organization (ISO) Working group TC184/SC5/WG1. Based on this, any kind of proposal for an enterprise integration RA can be evaluated under these criteria to get 'ISO and IFAC certification'.

6. Diagnosis of the current situation

Among the different existing architectures, only CIMOSA, PERA and GRAI/GIM could presently have the possibility to fulfill the GERAM requirements necessary to be considered an 'enterprise integration RA' by the IFAC and ISO entities, as ARIS and other proposal as CIM-BIOSYS (developed by the Systems Integration Group of the Loughborough University (UK), (Weston, 1993)) are oriented toward the development of an integrated information system, not toward the integration of the whole enterprise.

The comparative study realized in (Chalmeta, 1997b) of these enterprise integration architectures enables one to conclude that PERA develops to a high detail level the methodology to follow for the enterprise integration in each phase of the enterprise development program (Hong and William, 1994). However, it adopts a bottom-up construction focus of the enterprise functional system, defining at the beginning elementary tasks, and then gathering them into enterprise activities to satisfy the strategic objectives. This proposal could be possibly be improved by introducing the specific identification of the business processes in a top-down approach used to develop the data and material and energy flow diagrams.

On the other hand, the CIMOSA and GRAI/GIM architectures are focused on the construction of an *integrated model* to assist in enterprise design, but do not cover the whole life cycle of the enterprise. Moreover, they use different methodologies to model different views of the enterprise (informational, resources, decisional and functional), not offering any method to solve the resulting inconsistencies nor being able to construct a dynamic integrated model.

Another factor to take into account is that although there are different applications of the three architectures in real enterprises, it appears that they have been focused mainly on big manufacturing enterprises. So, it would be interesting to prove this architectures in the integration of different size companies involved in the life cycle of a product or service (supplier, manufacturer, deliveries, etc.).

Therefore, all these architectures can be improved, as they have not completely generated the necessary methodologies, modelling techniques and adequate execution tools for the different kinds of enterprises (Pantakar, 1995).

7. The ARDIN project

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 RA for Enterprise Integration. The work plan has been:

- Synthesizes the existing (and in our opinion) complementary approaches, in only one architecture. The earlier architectures have many good points, and we wish to take advantage of this.
- To improve the result architecture incorporating new techniques, methods, models and templates.
- To validate its usability and application, carry out real enterprise integration projects, mostly in the small and medium-sized enterprises of different sectors.
- To organize knowledge and experience obtained in our own architecture called ARDIN. This architecture is being built giving priority to its practical utility as project execution support in enterprise integration. A long range objective will be the achievement of the needed requirements and components to satisfy the GERAM requirements for a 'complete enterprise integration RA'.

8. Characteristics of a RA

The first activity of the project was to identify the 'characteristics' that the methodology and the reference models (the two main components of the architecture) must comply in order to carry out the enterprise integration project adequately (Tables 1 and 2). This work has been carried out independently of the GERAM work, so it can be compared with it.

9. The ARDIN architecture

After this work, we are now developing the ARDIN architecture. It is being developed with a strong orientation toward its practical application to medium and small enterprises, for which it bases itself on real studies of concrete enterprises.

Table 1
Methodology requirements of a complete architecture

Methodology requirements	
Complete	It must show a full vision of the enterprise and its relations with other enterprises.
Support for decisions taking	It must present the impact that a concrete enterprise development program generates in the enterprise, allowing to solve and select the one amongst other programs that improves the performance of the enterprise
Multi-disciplinar coordination	It must co-ordinate the set of disciplines that exist in the enterprise in order for the decisions to convey in one plan with common objectives
Structured analysis and design methodology	The architecture must consider all the enterprise. Therefore it must include several views. The technological, information, organization and human aspects must appear, as well as the relationships between them and their external elements
Abstraction levels	It must support the decisions making at strategic, tactical and operational level
Stardardization	The architecture must allow the standardisation of the evaluation criteria and of the methods and modelling tools in order to compare the results of the performance of the enterprise with the internal and external standards (benchmarking)

Table 2
Modelling requirements of a complete architecture

Modelling requirements	
Modeling technique	It must present a method to identify all the enterprise elements
Modularity	The architecture must provide a modular structure which has to enable to face the modelling process by parts, but assuring at the same time the consistent integration of all the modules
Open system	The architecture does not have to be a closed one. It must generate a model ready to be extended and adapted, reflecting the enterprise evolution in parallel with its environment and the technological improvements. They must provide the means to analyse changes, give them priorities and incorporate in the model the ones that are interesting for their evaluation in decisions taking
Global	It must be a global model of the enterprise which allow to shared and reused the knowledge included in it, for the decisions taking
Parametric	The model must be adapted to the concrete requirements of each domain
Maintainable	It must have upgrading capacity maintaining consistency
Simplicity	Implementation of the model must not be complex
Innovation	It must make easier the innovation capacity of the involved persons
Automatic maintenance	The model maintenance must be easily made by users
Supporting tools	It must offer a strong support of information technologies in order to create consistent and easily enhanced models
Permanent	The model must survive to the re-organization of the enterprise and be independent from the physical storage of information it uses
Useful	Easily understandable, strong and capable to work with the maximum interest areas

Among the main characteristics of the ARDIN architecture it can be shown that (1) it proposesan enterprise vision oriented toward *business processes*, (2) it establishes the life cycle of the enterprise system based on a *continuous improvement* process, (3) it uses *modeling* and *simulation* as tools to analyze the decision impact and (4) it describes a method to integrate and coordinate the *consistency* of the *decisions* and the operations with the strategic objectives.

The architecture uses the 'business process' *as the structural unit (subsystem) on which the integrated enterprise system is developed* This methodology allows to organise all the main enterprise elements *(activities, resources, information and decisions)* in order to maximize the value of the products and services that the enterprise offers and that the clients require.

For the graphical representation of every process, different modeling tools are used inside ARDIN. In order to speak to the managers of the enterprise, IDEF0 (CAM-I, 1981) for the operative tasks and GRAI nets (Doumeingts et al., 1992) for the management system are the best, because of their simplicity. In addition the object-oriented modelling allows the development of a 'dynamic enterprise integrated model', including all aspects normally modeled separately (functional, decisional, informational and resources). This model can be used to simulate and to evaluate the business process performance.

At the moment we have a prototype focus on the tile production process, and another focused on the transport industry (Chalmeta et al., 1997a). This prototype is now being adapted to the new object-oriented modelling language UML and it is being extended to cover all of the enterprise's internal and external processes.

The simplicity and capacity to highlight the different parts of the enterprise offered by IDEFO and Grai-Net techniques together with the properties of object-oriented modeling such as specialisation, collaboration,

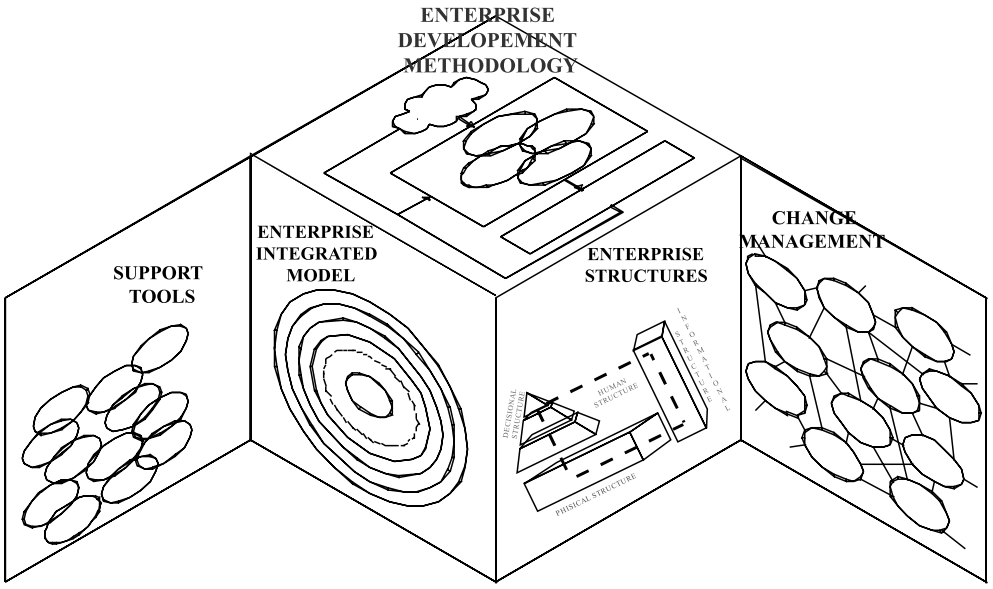

Fig. 5. The five dimensions of the ARDIN RA.

fractal composition, modulation, concurrence, scalability and the capacity to represent all enterprise elements together including dynamic behaviour, etc. (Taylor, 1995), allows the generated models to comply with the modelling characteristics defined in Table 2.

The ARDIN architecture is organized in 'five dimensions' (see Fig. 5):

1. *First dimension*: A step-by-step 'enterprise development methodology', to guide the construction of a *integrated enterprise-system* using the business process vision and capable of *dynamic evolution* depending on necessities and objectives. In (Chalmeta et al., 1996) some of the characteristics of the methodology are shown in more detailed.
2. *Second dimension*: An 'enterprise integrated model', which assists the enterprise design process, supporting the decision making from an integrated perspective. As noted above, the model is generated by an object-oriented interpretation of the business processes and of their basic aspects.
3. *Third dimension*: The formalization of the construction process from the model, of the different enterprise structures. At the moment we have developed with more detail the process of construction of an 'information integrated infrastructure' which groups the informational specifications required for the decisions and activities of the enterprise and ensures the necessary data flows and physical resources to co-ordinate them. However, the objective is to formalize the building of all the structures (definition and organization of the human resources, identification of the technological resources, etc.).
4. *Fourth dimension*: A set of 'support tools', based on the information technologies, which assist in the process of designing, evaluating, implementing, and controlling the integrated enterprise.
5. *Fifth dimension*: The '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.

10. Interrelation between the dimensions

The ARDIN RA is organized into five interrelated dimensions. However, from a more traditional vision, the Architecture can be represented as a unique dimension (the step by step development methodology, see Fig. 6) 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 *second dimension* describes the procedure to develop models which can be used as a support in the enterprise conceptual and design phases. The *third dimension* is focused on the construction and implementation of all enterprise structures, aspect that is included in the second phase of the methodology. The *fourth dimension* presents a set of tools (based mainly on information technologies) 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.

This vision in the ARDIN architecture emphasizes even more the strong existing interaction between the different dimensions. Moreover, it also justifies the Ar-

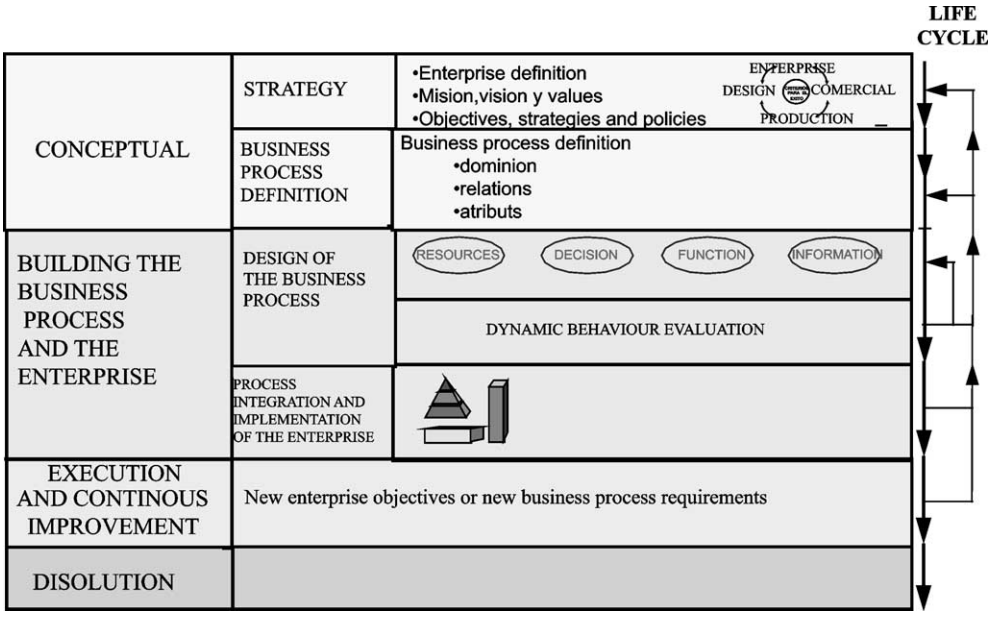

Fig. 6. ARDIN enterprise integration methodology.

chitecture name, as what is being proposed is not only a methodology or a tool, but a set of different elements that together enable one to successfully lead the enterprise integrated development process.

11. Applications of the ARDIN architecture

ARDIN Architecture has a strong orientation towards its practical application to enterprises. The IRIS group have applied the methods and techniques developed in the ARDIN Architecture to small and medium enterprises, as well as holdings and virtual enterprises of different sectors: chemistry, construction, transport, textile, information technology and governmental. The objective is that it can be applied to both new enterprises (at the constitution phase) and enterprises in the execution phase that want to improve their performance. However, at the moment all the work has been oriented more to real enterprises. For this reason, some of the tools that are going to be shown in this point should be adapted to the integrated design and implementation of new enterprises.

The enterprise integration programme that is proposed following the methodology of the ARDIN architecture, from a practical point of view, can be summarized as follows (see Fig. 7):

1. Definition of the conceptual aspects of the enterprise: the mission, vision, strategy, politics and enterprise values.
2. Design (re-design) of the new process map according to the previous defined concepts.
3. Implementation. Four steps should be done:
   - to sort the priority of short, medium and long term improvement projects obtained as a consequence of the new process map;
   - to implant improvement projects of highest priority;
   - to establish a quality control and insurance method;
   - to design a continuos improvement system to implant the medium and long term improvement projects and to define new goals or changes in the processes.
4. To organise and to manage human resources according to the process map. All the workers and managers have to know what their activities and responsibilities are (who, what, where, how and when).
5. To build the information system to support the process map of the company, considering the different decision levels and the support technology.

The above five activities within the enterprise integration programme have to be managed and controlled as an engineering project. The fundamental requirements to be successful in the project are: to sensitize the Directors of the company, to create a committee, to nominate a co-ordinator, to approve the scheduling and the internal diffusion of the project goals. Furthermore it is necessary to supervise the evolution of the project, in order to avoid resistance to change, to motivate the employees, to measure the amount of participation and to evaluate the results.

The activities, in which the enterprise integration programme is divided, according to the ARDIN architecture, are shown below. Some of the results obtained from the applications in different enterprises are also shown.

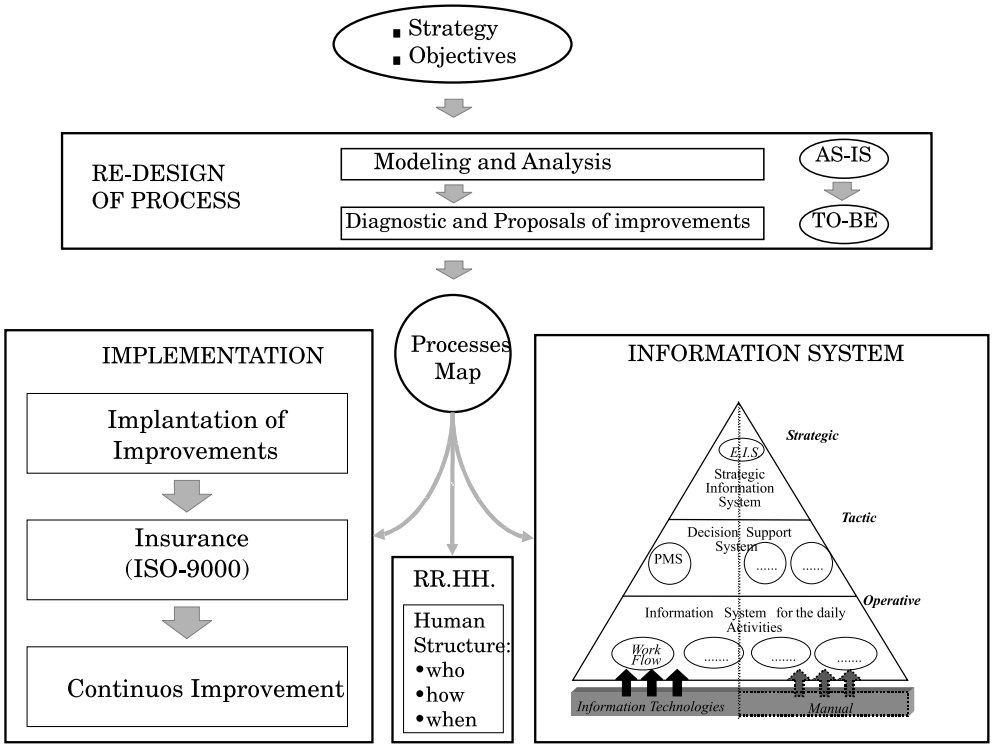

Fig. 7. Entreprise integration programme.

11.1. Conceptual aspects

The starting point within a program of integrated development is always the analysis of the enterprise goals (mission, vision and strategy) and its culture (politics and values). The fact that a company goes on and has good economic results, does not mean that it works efficiently and has defined its goals and responsibilities. So, it is very important, before beginning a new integration project, (1) to understand and to explain the enterprise strategy, defining where the company is, where it wants to go, and where it is actually going and (2) to analyse its culture and its internal organisation and control level.

11.2. Business process design

Once the strategy goals have been defined, the next step is to design the way to achieve these goals through the company business processes. To define the processes map, the actual situation (the AS-IS) has to be analysed and the new enterprise processes (TO-BE) must be designed. To do this, it is necessary to carry out questionnaires and interviews with the company workers. An example of the templates is shown in Fig. 8.

Two distinct approaches to carry out AS/IS–TO/BE analysis exist. For example, some authors say that in a 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. Our experience obtained in the integration of different companies 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 an enterprise operates may greatly change. These changes may stem from defining new processes or radically 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).

An interesting element to carry out the business process design and to reduce time and costs is the use of a reference model. A reference model describes how the processes should be using the best working practises and how the roles of the human resources should be. A reference model is built from a benchmarking of

JOB DEFINITION

Date: _____

Department: _____

Job: _____

Name of employee/s: _____

FREQUENCY (FREQ): D - Daily, **S** - Weekly, **M** - Monthly, **A** - Yearly, **V** - Variable.
COMPUTER SYSTEM (SIST): YES/NO.

TIME	DURATION	FREQ	MICROPROCESS	SIST

OBSERVATIONS:

_____

_____

DESCRIPTION OF A MICROPROCESS

MICROPROCESS: _____

Nº	ACTIVITY	DESCRIPTION	INPUT		OUTPUT	
			INFORMATION	ORIGIN	INFORMATION	DESTINATION

OBSERVATIONS:

_____

_____

Fig. 8. Example of questionnaires.

different companies in the same sector and similar processes from companies of other sectors.

Fig. 9 shows a process map diagram of the reference model of the tile industry developed by the IRIS Group. The big arrows show the tile industry macro-processes. Each macro-process is divided into micro-processes, activities, tasks, and so on until getting down to the lowest level, that is, the event produced by a human action or a machine. Every task of the model has inputs, outputs, controls and resources (see Table 3).

In addition to the operational part (activities realised), the model shows the information, the resources and the decisional alternatives for each activity within the process. Decisional alternatives represent the different ways of doing an activity and their election depends on the established goals for the process, according to the strategy and the politics of the company (see an example in Table 4).

Someone has to take these decisions. The process/function matrix should be completed in order to know

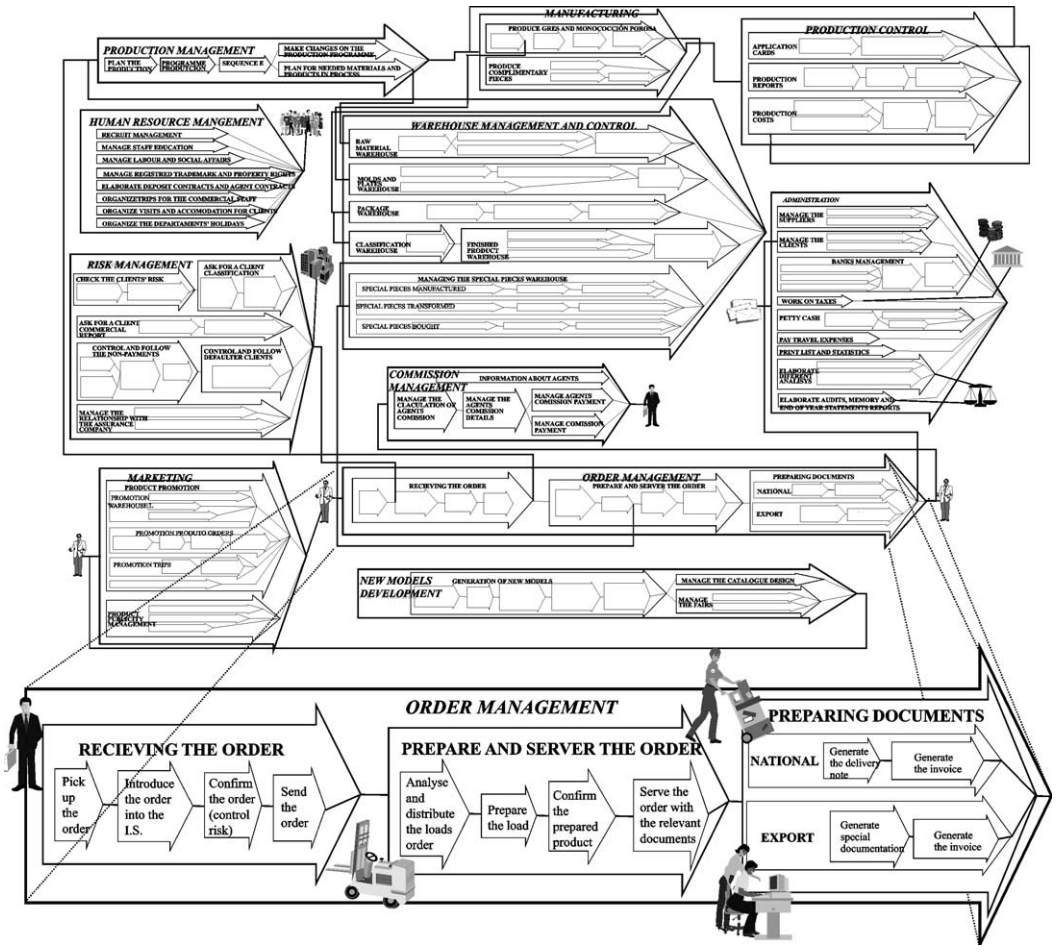

Fig. 9. Tile industry process map.

Table 3
Example of a task

Introduce the order into the information system (IS) The aim of this activity is to introduce the order in the IS Clients that place orders have already been introduced by the commercial area, who, in turn, have previously accorded payment conditions, sales conditions and prices with the client. Moreover, it has asked the risk area for client risk information. The order can arrive from two source, by phone call or fax, whether coming from the client or from the commercial agent. Independently of the source from which orders arrive, their reception is centralized in the expeditions department ...	
Inputs	Client order (telephone, fax, other media) Items information (code, size, quality, etc.) Client information (fiscal data, delivery address, etc.) Additional information of the client and/or the order provided by the commercial agent
Outputs	Order
Controls	Catalogue Prices Enterprise politics IS capacity
Resources	Sales area staff IS, telephone, computer, etc.

who is the owner of every process (see Fig. 10). In addition, Fig. 9 can be improved by coloring the activities carried out by personnel in the same department with the same colour. In this way, the figure represents the horizontal view of the enterprise by means of the processes and the vertical view by means of the departments.

Table 4
Example of decision alternatives

Decision analysis Situation 1	The client exceed the risk		
Decision 1	Decision 2	Advantages	Disadvantages
Introduce the order into the IS and wait until the commercial for director's authorization	Reserve demanded items	It will not load orders to high risk clients without a previous control by the commercial director A product reservation is made, and can be confirmed after the authorization	When a reservation is made, the available products will be kept for no risk clients only
	Do not reserve demanded items. They are kept only as information	Product that may not be served will not be reserved No risk client orders can be placed It will not load orders to high risk clients without a previous control by the commercial director	When the commercial director authorizes the order it is possible that the available product item is not available
Do not allow the introduction of the order into the IS			The commercial agent must find an alternative way to register the order, which will generate duplicity

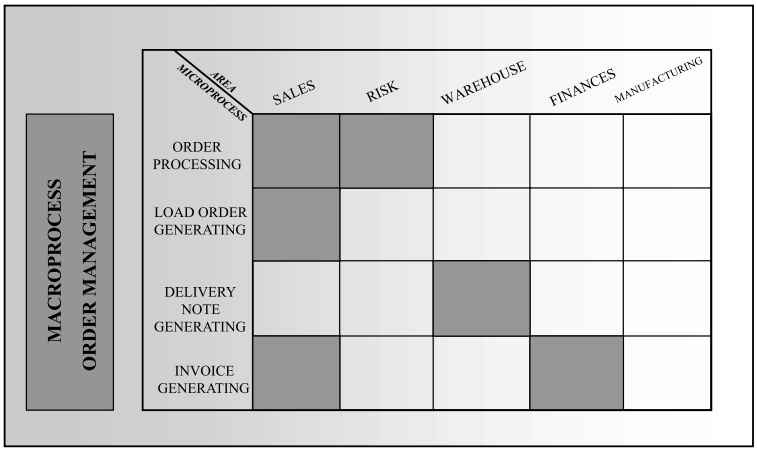

Fig. 10. Processes/functions matrix.

This reference model facilitates the business process design project in a tile company. It has reduced from four months to one the time required for the IRIS Group to carry out the whole study: the analysis of the AS-IS and the improvement proposals (TO-BE). On the other hand, this reference model has been used by Baan Business System (now Vanenburg Business Systems) to develop templates for the Tile industry of its software ERP, with the goal of reducing the cost and the time of the implementation of BAAN ERP in a tile industry.

Another reference model developed by the IRIS Group is oriented to road transport enterprises. This model has served to implant the working processes and to develop the information system in a Spanish virtual transport enterprise (Chalmeta, 2000). This virtual transport enterprise is a temporary alliance of 45 small and medium size enterprises that work together through the establishment of co-operative agreements, to share resources, skills, and costs, supported by Information and Communication Technologies in order to better attend market opportunities, to reduce the transportation cost and successfully fulfil a responsible corporate strategy.

11.3. Implementation

As a result of applying the business process design in a company, a new process map is designed. The next step is to implant and to control the migration of the old system (the AS-IS) in the new processes (the TO-BE).

Table 5 shows a template to begin the AS-IS/TO-BE analysis. This template is also appropriate for showing

small improvements in the processes since the AS-IS and the TO-BE activities will coincide, although they will be carried out differently. A significant re-design effort may result in a completely different set of activities, in which case another template model would be needed to show the process result regarding AS-IS.

The gap + restrictions column shows the differences between current work performance, desired work performance and the restrictions that exist to achieve the latter. In this way the TO-BE enterprise implementation may be broken up into a series 'of co-ordinated projects', that will be set in priority, and if the enterprise already exits, these projects will form the transition path from the AS-IS to the TO-BE enterprise. Traditional cost/benefits analysis is a very useful tool to define the priority of the projects within the integration program. However, organizational, technical and operational aspects should also be considered. Therefore, ARDIN can be used as the basis for feasible enterprise project identification, execution and management, all of which are within the financial, physical and economic capabilities of the enterprise and the requirements of the conceptual phase are met.

Once the projects have been prioritized, the short term projects must be implanted. It will mean changing attitudes, both in the directors of the company and the employees, defining new roles and redesigning the company structure. The results must be that everyone in the company knows its activities, knowing what to do and how to do it. In order to ensure that the desired changes have been properly implanted, a method for quality assurance (as for example ISO 9000) is necessary. Finally, a continuos improvement system must be designed, allowing (1) to implant in the future the medium and long term improvement projects and (2) to adjust the enterprise to the environmental changes. When these projects are completed, the integration desired will be completed.

11.4. Human resources

As a results of the integration project everyone in the company will know its activities, knowing what to do and how to do it. So it will be able to define the new company structure.

Table 5
AS-IS/TO-BE analysis

Area: Sales	Document code:EncAsisTobe	File:EasisTob.doc	
Macroprocess: Order management	Author:Pilar García García		
Microprocess: Order processing	Creation date:14-Apr-99	Modify date: 14- Apr-99	
Activity[a]	AS-IS[b]	TO-BE[c]	FIT[d]	GAP + Restrictions[e]
(1) Collect data about the order	The order is received via fax or telephone from the client. If the order is received via telephone, data is written down in an orders notebook to be introduced into IS afterwards	If the order comes via telephone, data must be introduced straight into the IS	NO OK	The IS dose not allow real time performance due to the complexity of the consultation be carried out during the data introduction. Restriction: IS
(2) Consult the client risk	Before introducing the order into the IS data about client risk must be consulted. If client risk exceeds the credit assigned, the IS dose not allow the introduction of any more orders. For this reason, it is necessary to write down the order	The order risk consultation option must be accessible from the order introduction option and must be updated with the introduction of each new detail line. The IS must allow the introduction of high risk client orders and the block them in order to avoid processing until their situation changes or a person in charge decides to block them.	NO OK	The IS dose not allow the introduction of high risk and it obstructs its consultation. Restriction: IS
(3) To introduce order data into the information system	Trough the option "New order", the head data and detail lines of the order are introduced		OK	

[a] The activity must coincide with the show activities in the textual description and the DEM.
[b] Describes how the activity is carried out at present.
[c] Describes how the activity must be carried out in the future.
[d] It must be know as follow: OK: if the activity is carried out at present in a desirable manner.; NOT OK: if the activity is not carried out according to a desirable manner.
[e] Describes the differences between the TO-BE and the AS-IS, showing possible restrictions to go from the AS-IS to the To-BE.

11.5. Information systems

A very important aspect in the company's integration is to co-ordinate the process activities in time and space through the transfer of information between the processes. "Information is the gum that keeps the organisation structure joined" (Rockast, 1988). The information is utilised to integrate the activities within a process and between many processes, since many times the information that has a process is useful to another one. Therefore the information systems are a basic element to integrate the company.

To build an appropriate information system presupposes establishing the relationships between the company, its activities and information management: how the information is generated, how it supports the company's operation and how it is managed. Therefore, the first step in the development of the information system is to define the information requirements to coordinate the decisions and to execute the activities from an integrated perspective.

In a traditional methodology for the development of an information system in a company, the requirement specifications are realised through a functional area analysis. For example, the marketing applications to solve marketing problems, the manufacturing applications to solve manufacturing problems, etc. As a consequence, the data utilised within one area cannot be utilised in another because this possibility has not been forecasted.

This unsuitability to reach the integration when information and enterprise activities are considered within the departmental boundaries suggests that it is necessary to collect the specifications of the information requirements through an analysis of the business processes.

The proposed model for the information system development by ARDIN architecture is oriented to the process map of the company. It guarantees the integration of the company's activities through the information, thus allowing the company to broaden the possibilities of using the information to increase the company performance. The information can be used to measure and monitor process performance, to improve its design and execution, to integrate the activities within and between the processes, to fit the processes to the clients, to facilitate the long term plans, to support the decisions related to the activities, to control the strategy evolution, etc.

Finally, it is necessary to point out that in an information system oriented towards functional areas, it is very difficult to come to conclusions about the processes and the enterprise performance. Only when the information system is oriented towards processes, enough information is generated to study how good the company processes are. In this way, computers are capable of gathering information on and reporting about resources consumption, the time, cost, etc.

One aspect that must be emphasised is the need to separate what is manipulable (information) from the element that executes the manipulation (information technology). A lot of the information that circulates through the company is not taken into account by the information technology, but rather can be supported by other means, like paper, telephone or oral transmission. In this paper, the 'information systems' and the problematic related to its design are oriented to a computerised information system.

A company processes map defines the requirements of the information system which will be used (1) to develop a customized software or (2) to compare the ERP software currently on the market in order to select the most appropriate one for the enterprise objectives and processes. The exhaustive requirements definition carried out according to ARDIN architecture also serves to obtain a closed contract regarding time and cost with the enterprise that develops or implements the software. Fig. 9 shows, as continuous lines, some of the information in and between the processes of the reference model of the Tile Industry and Table 6 shows some of information requirements of the tile industry reference model.

Therefore, those activities for enterprise integration, according to the ARDIN architecture, related to enterprise strategy analysis, enterprise processes map redesigning, improvement projects defining, etc. must be carried out before choosing whether to develop a customized software or to adopt a standard ERP. In this way, an alignment between the information system and

Table 6
Example of functional requirements of the IS

Process: order management
Requirements of the IS
The IS must facilitate the consultation of articles available in the warehouse showing whether the product is reserved or not
The IS must allow the introduction of order lines of articles which are not in stock
The IS must give knowledge about client risk status when the order is introduced
The IS must allow the easy generation of the load order which marks the order lines of a determined client's pending orders
The personnel in charge of the warehouse may consult other locations in the warehouse and modify them on the load order
When the delivery note is generated, the previous associated documents must be updated properly; that is, the lines that have been served must disappear from the order and the corrections affecting warehouse stock must be updated

the enterprise strategy is achieved. In other hand, it is shown that Ardin architecture is useful for both the development of customized systems as well as for standard ERP software implementation.

12. Decision support system

Decision support systems (DSS) are part of the information system and support the tactical and strategic decisions. The performance measure systems and the cost models are examples of DDS that are very useful for any kind of enterprise and are a powerful tool for improvement if used along with enterprise integration. They are necessary to prescribe, suggest and assist in the design and management decision-making phases.

The kernel of a performance measurement system is a set of indicators that can be classified from six perspectives: customer, financial, internal process, learning and growth, quality and environmental. This set of indicators can be employed as the foundation of an integrated and iterative strategic management system. It enables the VTE company to:

- clarify and update strategy;
- communicate strategy throughout the company;
- align unit and individual goals with the enterprise strategy;
- link objectives to long-term targets and annual budgets;
- conduct periodic performance reviews to learn about and improve strategy.

Inside the ARDIN project, a performance measure system for a virtual transport enterprise has been built. This system allows controlling both, the performance of a company part of the group, and the performance of the whole group. In order to develop the performance measurement system for a VTE we have followed the methodology derived from the work carried out by members of the IRIS group under the project TQM-tile funded by the ESPRIT program of the European Union.

13. Conclusions

The complexity of the enterprise action framework, forces the enterprises to adopt an organizational and operational focus which will allow them to obtain the 'maximum benefit' from their resources. To reach this objective, an enterprise must 'efficiently manage' all its elements, aligning and 'integrating' them so that they work together toward the achievement of the enterprise objectives and strategy.

The project of master planning and implementation of an 'integrated enterprise system', from the above proposal, is an extremely complex process which involves different technological, human and organizational elements. To make the study of existing systems and the design of new more advanced systems, easier, reducing at the same time the complexity level, it is necessary to establish a step by step development 'methodology' and to formalize the creative process of each phase.

In this way, various efforts in the development of models and methodologies to analyze and design integrated industrial systems (called usually RA) are being carried out. However, the current paradigms are not fully complete, as the modeling methodologies, representation techniques and adequate executing tools have not been fully developed.

Within this framework, the 'ARDIN Project' has been shown. The implementation of an integrated system using the ARDIN proposals will allow the enterprises:

- to obtain a most efficient, flexible and versatile organization, by means of the combination of the vision of the enterprise management through the business processes, with the support offered by the information technologies for its design and execution;
- to elaborate a homogeneous reference frame within the company that allows verifying that the activities carried out and the services offered have an appropriate quality level;
- to integrate the value chain, which has an effect on management improvement, by decreasing global costs and increasing service quality;
- to establish a procedure to guarantee the validity and the renewal of the process in order to reach different strategic objectives as they are identified successively;
- to involve the future users so that when the new process map implanted, it will have a positive development;
- to create a cultural change factor among the company staff by looking for a more participant management style and introducing continuous improvement processes in its activities.

The project implantation will mean establishing a new and better intercompany relationships.

Acknowledgements

The ARDIN project is being founded by Cicyt, Bancaja and different enterprises.

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