Towards the Virtual Enterprise in Food Industry

*L. M. Camarinha-Matos *, R. Carelli**, J. Pellicer**, M. Martín***

**New University of Lisbon and Uninova*

Faculty of Sciences and Technology

Quinta da Torre - 2825 Monte Caparica, Portugal

E-mail: cam@uninova.pt

***Universidad Nacional de San Juan*

Instituto de Automática

Avd. San Martin - Oeste 1109, 5400 San Juan, Argentina

E-mail: RCARELLI@inaut.unsj.edu.ar

Abstract

The case for the development of the Virtual Enterprise concept in the Agribusiness sector is presented. Current tendencies and the strategy of an European - Latin American project (SCM+) are discussed. A preliminary Petri net model of the interactions in a food supply chain is illustrated as part of the approach to assess current situation and characterize the information infrastructure needs. Finally, a summary of the major functional requirements for a Virtual Enterprise reference architecture is presented.

Keywords

Virtual enterprise, supply chain, Petri nets, Agribusiness, Electronic Commerce.

1 INTRODUCTION

The paradigm of virtual enterprise is becoming more and more important in the manufacturing industries nowadays. The manufacturing process is not any more carried on by a single enterprise, but each enterprise is just a node that adds some value (a step in the manufacturing chain). In virtual enterprises, manufacturers do not produce complete products in isolated facilities. They operate as nodes in a network of suppliers, customers, engineers, and other specialized service functions. Virtual enterprises materialize by selecting skills and assets from different firms and synthesizing them into a single business entity.

This tendency creates new scenarios and technologic challenges, specially to Small and Medium Enterprises (SMEs). Under classical scenarios these SMEs would have big difficulties -- due to their limited human and material resources -- to have access to or to use state of the art technologies but, at the same time, the new electronic-based inter-relationship imposes the use of standards and new quality requirements.

The effort being put on the implantation of high speed networks (digital highways), supporting multimedia information, open new opportunities for team work in multi-enterprise - multi-site networks. This new scenario brings new requirements in terms of exchanging, sharing,

managing and controlling information related to the products being produced. One key area is control; for example, access rights to product information, scheduling of information access, control of interactions. These requirements impact the design, availability and cost of appropriate distributed information logistics infrastructures.

As for the agriculture and food industry, this move towards virtual enterprises is not so developed yet. Nevertheless to the SMEs involved in food processing industry, it is becoming clear that a real competitive advantage can only be achieved and sustained through the creation of relationships and strong information links and co-working among the enterprises involved in the various steps of the value chain. In our view the creation of **virtual enterprises** is inevitable in order to efficiently utilize all of the relevant human, organizational, and business resources and to facilitate the necessary interdependencies between the suppliers (farmers and others), manufacturers, distributors, sellers and ultimately customers.

It shall be noticed that, besides the simplified supply chain (Fig. 1), producing a consumer product in modern food industry involves producing a sequence of intermediate products / services. Each of these intermediate components is used as an ingredient or raw material to make the next product in sequence (value chain).

Figure 1 Simplified supply chain.

For instance, in the production of canned tomato paste, the enterprises which might work together to constitute a virtual enterprise include wholesalers and retailers, can producers and their supply chain, food processors and packers, farmers and fruit growers, transportation and delivery enterprises. That is the realization of the **agribusiness concept** defined as the set of all operations involved in the processing and distribution of the agropecuary products, the production operations within the farm and the storing, processing and distribution of all agropecuary products and their derivatives. This increases the need for greater communication and coordination among specialists in value-added partnerships. Emerging Information Technology capabilities such as EDI-Electronic Data Interchange, federated multi-agent architectures, STEP-Standard for Technical data Exchange on Products, etc., support the emergence of the virtual enterprise. Inter-enterprise and intra-enterprise networking across the value chain can be supported by today's advances in computing and telecommunication technologies and their emerging integration into the Information Superhighway.

This paper presents the approach and some preliminary results of the work being developed in the context of the SCM+ (Beyond Supply Chain Management in Food Industry) project (SCM+ 95). This is a cooperative project funded by the INCO-DC program of the European Commission and involves research groups and companies from the European Union and Latin America. Due to the complexity of the addressed problem, in our opinion, the design and development of a Virtual Enterprise concept in food industry should be addressed through a two-phase approach. The first phase is devoted to study and analyze food value added chains in

Latin America and carry out a feasibility study on the potential for an Extended Enterprise approach. The consortium is planning to address the second phase of the project, namely the possible implementation of a pilot Extended Enterprise involving the various actors in the chain, viz. farmers, processors, distributors, etc., as a follow up project to SCM+. Clearly, the results of the feasibility study stage are absolutely necessary input to a possible second phase and indeed follow on project.

The SCM+ project involves several diverse application domains - tomato-paste, olives, coffee, milk, marmalade, etc. - within the food industry, including SMEs involved as associated partners in the project. As a first step, this study concentrates on the strong existing links between the producers (farmers) and the food processing enterprises in Latin America. The project is studying the current situation and analyzing the requirements set by the technological, organizational, social, business process reengineering (BPR), etc. aspects of this industry and the needs to be considered in applying the supply chain management and Virtual Enterprise approach. This stage will be followed by the evaluation of the impacts and benefits that are likely to result for the SMEs in food production through the creation of an integrated network and associated information network within the supply chain. In parallel to the problem analysis and the study and design of a virtual enterprise for this industry, some efforts are being spent on the evaluation of other complementary functionalities that can be supported by an information network, such as on the effect of the management of seed distribution, integrated pest management, and multi-media based training on agricultural techniques and advanced technologies. Due to the limited resources available, the effort devoted to these complementary aspects is, however, minimal.

Today the Latin American economy offers a challenging and fluctuating market. This market is dynamic in terms of the demand and the financial and social states of its consumers, competitive and hard to forecast in terms of the capital and investments in the short term and long term products and rapidly improving in terms of the technology development, the quality and expertise of its technical and supervising manpower, the equipment it employs, and its participation in the global market. Global economic associations such as the MERCOSUL / MERCOSUR are expected to have major impacts in the region.

In addition to the timely, competitive, and cost effective production, an important aspect of the Virtual Enterprise 'model' is the potential it offers to help those involved in the very early stages of the food chain, namely the fruit producers and farmers. Developing and successfully commercializing differentiated products that appeal to consumers is a surviving condition for some peripheric regions but this requires the organization of increasingly complex partnerships (Holt 95). A Virtual Enterprise approach would involve the food processors working very closely with their supply chain, namely the farmers and fruit producers and supporting them with invaluable advice on the choice of seed and plant, disease control, protection of plants against insects, and the selection, supply and use of appropriate fertilizers etc. Such an approach clearly is necessary to upgrade the productivity (and therefore the economic and social conditions) of these farmers and to ensure regular supply of high quality raw materials to the food processors.

2 GENERAL OVERVIEW

2.1 Current developments

The application / development of the concept of virtual enterprise in the Agribusiness / Food Industry is still very limited. One of the few related works is the CYBERFARM initiative (University of Illinois at Urbana-Champaign), which is still a simple experiment on the use of Internet to support farmers (www.ag.uiuc.edu/aim/demo/ccnet.html).

On other economic sectors, however, a growing interest can be noticed (Walton 96).

The most important initiative is the NIIP - National Industrial Information Infrastructure Protocol (NIIP 96), which is a very large American project, involving 18 partners (enterprises, universities and government organisations), led by IBM and with a budget of 60 million US \$. NIIP goals are: to adopt and develop, demonstrate and transfer into wide-spread use the technology to enable industrial virtual enterprises. This project, now on its second year, has produced already a huge amount of documentation, publicly available (www.niip.org), including a reference architecture, characterisation of various scenarios for virtual enterprises and detailed proposals regarding the various components of the architecture.

At the European level the situation has evolved from an initial "fragmented" approach to more integrated projects. Two of these projects are the recently started Esprit PRODNET II and LogSME. The SCM+ consortium intends to keep contact with these projects. Other related projects are the Esprit X-CITTIC and PLENT.

At national level, various recent initiatives can be found from which major results are expectable in the near future.

Finally, it shall be mentioned that there is a large number of activities in other areas that can provide supporting technologies, like Workflow and EDI.

2.2 Modeling challenges

As the Virtual Enterprise paradigm is new, there aren't yet specific tools, methodologies or an established modeling tradition in this area. A pragmatic approach is to "borrow" methods and tools used in the software engineering and manufacturing engineering areas. But it is our belief that adaptations are necessary. Establishing a platform to a Virtual Enterprise is not creating something from the scratch. Enterprises already exist as well as their cooperation practices and some support tools. Therefore, the process has to start with a Situation Analysis, involving modeling and evaluation of current systems and processes. Then a Requirements Specification can be made, mainly focused on the desired improvements and having as guideline a Reference Architecture. Some promising tools from other areas are:

Modeling Tools

i. Classical tools.

Generic CASE tools - Classical Systems Analysis methodologies and modern CASE (Computer Aided Software Engineering) tools offer graphical representations for functional and data models.

Manufacturing Engineering tools - A number of tools have been used in the practice of manufacturing systems engineers and researchers. Some of the most popular are:

Functional modeling: SADT / IDEF0, CIM-OSA BP/EA, DFD - Data Flow Diagrams, etc.

Data modeling: EE/R (Extended Entity Relationship model), IDEF1, EXPRESS - the modeling language used in STEP, Object Oriented representations, etc.

Dynamic modeling: Petri Nets, in various "dialects"/extensions, STD (State Transition Diagrams), IDEF2, IDEF3, Rule based systems.

Telecommunications Engineering tools - A number of tools developed in the area of telecommunications and distributed systems to model protocols and the behavior of dynamic distributed systems can be useful for modeling some aspects of the Virtual Enterprise platform.

-SDL - Specification and Description Language . Although it is standardized by ITU (International Telecommunication Union), SDL is not restricted to describing telecommunications services, but it is a general purpose description language for communication systems.

-LOTOS - Language of Temporal Ordering Specification. A formal specification technique for specifying concurrent and distributed systems, consisting of a language for specifying processes and an algebraic specification language called ACT ONE. G-LOTOS - Graphical representation of LOTOS concepts

-Estelle.

ii. Formal approaches

The use of formal methods with a strong algebraic foundation is calling the attention of complex systems developers. Some of the most popular methods used nowadays are: Z, VDL (Vienna Development Method) and RAISE (Rigorous Approach to Industrial Software Engineering). These formal approaches are starting to appear in the VE area [Janowski 96].

Reference architectures

A Virtual Enterprise Reference Architecture will be a general model describing an abstract Virtual Enterprise in various stages of its development, with each stage described from various points of view (functions, information, resources, behavior, etc.). Once a Reference Architecture is established, the model of a particular VE could be derived or instantiated from it using an appropriate methodology. Again, some approaches and concepts can be borrowed from other areas:

i. Model-based architectures

CIM architectures - Several attempts to establish Reference Architectures for industrial enterprises have been made. These architectures, being focused on a single enterprise, do not fit with the needs of virtual enterprises but can be useful in two ways:

1. Giving a general overview of the global structure, in its multiple views, of a generic industrial enterprise (a node in the virtual enterprise network).
2. Suggesting an approach for the definition of a VE Reference Architecture.

Some of the most well known Reference Architectures are:

- CIM-OSA - Open Systems Architecture for CIM
- PERA - Purdue Enterprise Reference Architecture
- GRAI - GRAI Integrated Methodology
- GERAM - IFIP/IFAC Generic Enterprise Reference Architecture and Methodology

GERAM is not another proposal for an enterprise reference architecture, but it is meant to organise existing enterprise integration knowledge, unifying existing architectures rather than intending to replace them.

Multi Agent Systems

One approach to VE modeling is to consider it as a multiagent system (each node in the network as an intelligent agent). In this way it is worthwhile looking at results coming from the MAS community, namely in terms of:

- Organizational approaches for MAS
- Interaction languages for MAS. For instance the KQML language.

ii. Technology-based architectures

In the specific area of Virtual Enterprises some attempts are already being done in order to establish Reference Architectures. The most significant (in size) is NIIP (National Industrial Information Infrastructure Protocols). Another example can be found in the Esprit PRODNET project .

To create a support infrastructure for VE, it is therefore necessary to put a considerable effort in modelling and defining a reference architecture.

The general approach chosen in this project starts at the analysis of current procedures followed by food industries and agro-producers - farmers/suppliers, existing production management and control software, and the evaluation of its extension towards the cooperation network philosophy taking into account the reality of SMEs and the context of developing countries. Existing results, namely in terms of standards for EDI (Electronic Data Interchange) and STEP (STandard for Exchange of Product model data), are being evaluated for their suitability for adoption as standards applied to the food industry. Other results from Integration in Manufacturing, (the Extended Enterprise), Business Process Reengineering (Design of Supply

Chains), the management of renewable resources in food production, sustainable improvement in agriculture and agro - industrial production, and crop disease prevention will also be integrated.

To illustrate the applicability of one "classic" modeling formalism to this application domain, next chapter introduces some preliminary results of using Petri nets to capture and assess the dynamic process behavior of an example supply chain.

3 APPROACH TO MODELING THE SUPPLY CHAIN USING PETRI NETS

The interrelationship between the enterprises participating in the value chain, is mainly governed by events which represent the forwarding or reception of relevant information -data, orders, receipt acknowledgements, etc.-, as well as the physical interchange of products. Therefore, the main focus in searching adequate dynamic modelling methodologies and tools should be set on the representation of discrete-event systems. Additionally, continuous system representation could complement the models, when trying to refine the model in order to realistically represent the time lapses involved in some events (Bernhardt, 1994 ; Carelli, 1995). The model should be able to capture the dynamic nature of the interactions as well as an adequate representation of the dynamics of each component of the value chain.

This section presents an approach for dynamically modelling the supply chain in the context of the extended enterprise concept. The model is a simplified version of a real food company described with some detail in (Carelli, 1996a). Different elements and relationships of the chain have been considered, including particular cases as the model for the supplier of raw material, the supplier of supplies and commodities for production, the client as well as the producer-factory relationship considering different situations, the supplier-factory and the factory-client relationships (Carelli, 1996b). In the following, a very simple producer-factory relationship model is presented.

In recent years, many techniques for modelling discrete-event systems have been developed. Among them, the following ones can be mentioned: Markov processes and their imbedded Markov chains, Petri Nets, queuing networks, automata and finite-state machines, finitely recursive processes, min-max algebra models, and discrete event simulation and generalised semi-Markov processes (Cao, 1990), (Ho, 1989).

Petri nets represent a tool for modelling systems with interacting and concurrent components. It represents an analytic and graphical approach useful for modelling, analysing and simulating discrete event dynamic systems. This section makes use of Petri nets for dynamically modelling the value chain applied to the food industry, considering as a first approach two elements of the chain: the producers and the factory.

3.1 Approach to Modelling The Supply Chain: Producer-factory relationship model.

Characteristics: Producers of tomatoes from Northern Argentina (production: 25,000 Tn) offer their production to the factory in San Juan-Argentina. The factory places an order for 100 trailers. San Juan producers (21,000 Tn) offer their production to the factory. This latter approves a shipment of 840 trailers. Mendoza producers (26,500 Tn) offer their production. The factory places an order for 1060 trailers. With all this raw material, the factory plans to elaborate 50,000 Tn tomato sauce. The Petri net model is presented in figure 2.

Figure 2 Producer-Factory chain PN model.

PN elements description: Following, the interpretation of places and transitions of the Petri net model is given.

Places

p1 : Initial condition for Northern producers.
 p2 : Production enabling.
 p3 : Tomatoes ready to be cropped (Northern producer).
 p4 : Total tomato volume to produce (Northern producer).
 p5 : Tomatoes cropped to be shipped (Northern producer).
 p6 : A 25 Tn tomato trailer is sent from the Northern producer to the factory.
 p7 : Tomato trailers in queue at the factory.
 p8 : Initial condition for San Juan producers.
 p9 : Production enabling.
 p10 : Tomatoes ready to be cropped (San Juan).
 p11 : Total quantity of tomatoes to produce (San Juan producers).
 p12 : Tomatoes cropped to be shipped (San Juan producers).
 p13 : A 25 Tn tomato trailer is sent from the San Juan producer to the factory.
 p14 : Initial condition for Mendoza producers.

p15 : Production enabling.
 p16 : Tomatoes ready to be cropped (Mendoza).
 p17 : Total quantity of tomatoes to produce (Mendoza producer).
 p18 : Tomatoes cropped (Mendoza producer).
 p19 : A 25 Tn tomato trailer from the Mendoza producer is sent to the factory.
 p20 : Offer from the Northern producer.
 p21 : Offer from the Northern producer is received at the factory.
 p22 : The order for one 25 Tn tomato trailer delivered to the Northern producer.
 p23 : Offer from the San Juan producer.
 p24 : Offer from the San Juan producer is received at the factory.
 p25 : A 25Tn tomato trailer order is delivered to the San Juan producer.
 p26 : Offer from the Mendoza producer.
 p27 : Offer from the Mendoza producer is received at the factory.
 p28 : A 25 Tn tomato trailer order is delivered to the Mendoza producer.

p29: Monitor of tomato orders.
 p30: Tomatoes in stock at the producer's, ready for shipping to the factory.
 p31: Quantity of tomatoes to be processed.
 p32: The factory produces 50,000 Tn tomatoes.

Transitions :

t1: Enabling for starting production in the North.
 t2: A Northern farmer produces 25 Tn of tomatoes.
 t3: 25 Tn of tomatoes are cropped.
 t4: A 25 Tn tomato trailer is sent to the factory.
 t5: Trailer arrives at the factory.
 t6: Trailer is unloaded in the factory's warehouse.
 t7: Enabling for starting production in San Juan.
 t8: A San Juan farmer produces 25 Tn of tomatoes.
 t9: 25 Tn of tomatoes are cropped in San Juan.
 t10: A 25 Tn tomato trailer is sent by the San Juan producer to the factory.
 t11: Trailer arrives at the factory.
 t12: Enabling for starting production in Mendoza.
 t13: A Mendoza farmer produces 25 Tn tomatoes.
 t14: 25 Tn of tomatoes are cropped in Mendoza.

t15: A 25 Tn tomato trailer is sent by the Mendoza producer to the factory.
 t16: Trailer arrives at the factory.
 t17: A Northern farmer tells the factory that he has available 25 Tn of tomatoes.
 t18: The factory approves and places an order for this 25 Tn tomatoes offer.
 t19: A San Juan farmer tells the factory that he has available 25 Tn of tomatoes.
 t20: The factory approves and places an order for this 25 Tn tomato offer.
 t21: A Mendoza farmer tells the factory that he has available 25 Tn tomato.
 t22: The factory approves and an order is placed for this 25 Tn tomato offer.
 t23: 25 Tn tomato are processed.

PN initial marking :

k1: 100 trailers unit.
 k2: 840 trailers unit.
 k3: 1060 trailers unit.
 k4: 2000 trailers unit.

Conflict Resolution. A typical conflict arises when the factory receives offers from a larger number of producers than needed for the planned industrialised production. Therefore, the factory has to decide which producers are to fill the needs. In the Petri net model, this conflict is evidenced by a conflict in transitions t1 to tn respecting place p1 (see Fig. 3). A supervisory model becomes imperative, and this is inserted at a higher Petri net layer.

Figure 3 Supervisor Module for solving conflicts.

In the model of extended enterprise concept, certain decision-making mechanisms are necessary in order to modify or fit the model's configuration to any given situation. A proposal for solving this, though still under elaboration, consists in supervisor module for modifying the Petri net models for each producer and their interrelationships with the factory.

3.2 Simulation Example

To show the feasibility of modelling the linking between actors in the value chain using Petri nets, the PASCELL software (Colombo, 1994) is used to simulate the above described model. This software allows the edition, modelling, simulation and analysis of discrete event systems through Petri nets.

Values for a real factory has been taken for the simulation, considering a scaling in time and product volumes, in order to simplify this example. A 50-day cropping season was chosen. The Northern region produces in the first five days the 5% of the factory's needs. At day 3, San Juan begins production of 42% of the factory's needs. At day 15 Mendoza begins production of 53% of the factory's needs.

A total production of 500Tn is taken with 5Tn trailer capacity, thus making 5 trailers from Northern Argentina, 42 trailers from San Juan and 53 trailers from Mendoza

Fig. 4 shows the Gantt diagram for the first 55 hours of simulation. The bars corresponding to T1, T6 y T10 are referred to the initial conditions for the beginning of production in the three areas considered. The bar corresponding to T2 refers to the Northern production. Lines T15 y T16 represent the communication links between the producers and the factory. It is noted there is one line for each 5Tn trailer the factory places an order for. The bar T3 is referred to the forwarding of trailers from the Northern producers. Bar T5 refers to the unloading of trailer into the factory's warehouse .

Figure 4 Gantt diagram.

Fig. 5 shows the Gantt diagram continued from Fig 4. At hour 64, the last Northern trailer is sent to the factory. (bar T3). At hour 68, San Juan production begins (bar T7). Bar T8 shows the beginning of San Juan trailer shipments. Bar T14 has no interruptions due to the continuity of the industrial production at the factory's plant.

In this chapter, Petri nets have been proposed as a promising tool for modelling and analysing the value chain producer-factory within the virtual enterprise concept. Petri nets provide useful models which capture the precedence relationships and structural interactions of stochastic, concurrent and asynchronous events. Conflicts can be modelled and deadlock situations in the system can be detected. Petri nets are a mathematical and graphical tool with a well developed mathematical and practical foundation. Timed Petri nets allow for the quantitative analysis of the value chain models. A first approach for modelling the food value chain has been presented and illustrated through a simulation example.

Figure 5 Gantt diagram (continuation).

4 TOWARDS AN ARCHITECTURE

The establishment of a support platform for VE can be analysed from various perspectives:

- **Virtual Enterprise creation**

Considering a VE as a temporary and dynamic (i.e., with variable "geometry") organization that appears in reaction to a business opportunity and is disbanded on the completion of this business process, a number of supporting functionalities can be identified. For instance:

- Selection of potential partners and negotiation of agreements

Various policies can be considered, like an open market approach (public call for tenders), based on privileged lists, etc..

The negotiation process, although strongly interactive as the ultimate decisions are human made, could be supported by the contract-net approach of the Distributed Artificial Intelligence community.

- Provisions for joining / leaving a VE, including the appropriate management of all consequences in terms of fulfilment of agreed duties and information access rights.

- Definition of the network topology and coordination approach.

Different levels of integrated coordination can be envisaged. For instance, a star-like structure with a dominante node, or a more "democratic" value-chain without dominant enterprise.

- Auxiliary functionalities to monitor and parametrize the network behavior. One of the important issues here is the identification of who will perform this function in the case of a "democratic" value-chain.

• Virtual Enterprise operation

Once a VE is established, the following points are some important goals to be achieved by such web interconnection from farmers to point of sales and crossing all intermediate nodes - manufacturers and distribution centers.

a. Efficiency of orders flow - with the extensive use of EDI standard, instead of fax, to support the orders follow up and with the possible adoption of STEP for the exchange of product data, as a support standard to the flow of information between nodes.

b. Follow up of orders evolution - fax or other non-electronic media lead to a non-effective monitoring of the orders evolution. Delays in orders processing, temporary incapacity of a supplier, the need to re-adjust delivery times, etc., are some factors that point to the need for a more flexible and reliable interchange of information. A client node might want to know the status of processing of its orders at the supplier's site in order to prevent any difficulties for itself.

c. Management and exchange of orders information among SMEs - a distributed information management system can guarantee the cooperation between the nodes, in the form of :

- an open computational infrastructure;
- sharing and information exchanging between all nodes, but preserving their local autonomy;
- privacy and safety for some parts of nodes' information.

d. Distributed and dynamic scheduling - scheduling is one of the most important activities in any manufacturing/production system. In the context of virtual enterprise in food industry, there is a scheduling function at each node and a scheduling at the network level. Breakdown of production originated by some disease or other unexpected event, changes in priorities, etc., may require the transfer of orders from one node (producer) to another. Thus, there is a need for an infrastructure which supports negotiation between nodes for workload distribution / contract assignment. Therefore, besides a distributed scheduling system, it is also expected a decision support system that helps a node to make decisions based on an updated knowledge of the current status of the network and historic information regarding the performance, quality, and reliability of each node (supplier) (Rabelo 96).

Of course this functionality is calling for a high level of coordinated control (with the consequent reduction of the local autonomy) for which some companies might not be ready yet.

e. Quality information
Sharing and keeping track of quality information along the value chain.

• Complementary benefits

As mentioned before, once a networked infrastructure is established, a number of complimentary services could be supported as well. Examples:

- Distance training
- Dissemination of information on IPM (Integrated Pest Management)
- Advice on seasonal procedures
- Etc.

In this particular area, and due to the isolated conditions of some farms, it is foreseeable that a large number of services can emerge on the network.

Current research activities in SCM+ are addressing these issues in an attempt to define a reference architecture for a VE particularly suited for this business domain.

5 CONCLUSIONS

The virtual enterprise paradigm seems to be a promising, even mandatory, approach to help the agribusiness sector facing current market challenges.

Although there is a great deal of interest for virtual enterprises in many manufacturing areas, the situation is still in its early stage when it comes to the food industry.

The SCM+ project is an international cooperation initiative aiming at characterising the needs, defining a reference architecture and implantation mechanism, and evaluate the foreseeable impacts and organizational changes.

The project is still in its early phase, but preliminary results show that it is possible to adapt various modelling techniques and methodologies developed or used in other areas, like CIM.

6 REFERENCES

- Bernhardt R., Schreck G., Colombo W., Carelli R. "Integrated Discrete Event and Motion Oriented Simulation for Flexible Manufacturing Systems". *Studies in Informatics and Control*. Vol. 3, Nos. 2-3, pp. 209-217, September 1994.
- Cao X.-R. and Ho Y.-Ch. Models of discrete event dynamic systems. *IEEE Control Systems Magazine*, Vol.10, No.4, June 1990.
- Carelli R., Colombo W., Bernhardt R., Schreck G. "Discrete Event and Motion - Oriented Simulation for FMS". BASYS '95. *Balanced Automation Systems. Architectures and Design Methods*. Ed. Chapman and Hall, pp. 363-372. Brasil. 1995.
- Carelli R., Martín M., Pellicer J., Masiello A., Oviedo W. "Frutos de Cuyo : Characterization of the relationships with suppliers and customers", 1st. Technical Report, SCM+ Project, May 1996.
- Carelli R., Pellicer J. "Feasibility study of Petri Nets Modelling of the Supply-Production-Client Chain", Technical Report, SCM+ Project, May 1996.
- Colombo W., Pellicer J., Martin M. and Kuchen B. "Simulator for FMS using Timed Petri Nets" (In Spanish : Simulador de Sistemas Flexibles de Manufactura usando Redes de Petri Temporizadas). *Proceedings on X Congreso Brasileiro de Automática - VI Congreso Latinoamericano de Control Automático*, Vol. 1, pp. 100-102. Río de Janeiro, Brasil. September, 1994.
- Ho Y.C., Ed. Special Issue on Discrete Event Dynamic Systems. *Proc. IEEE*, Jan. 1989.
- Holt,D.A. ; Sonka, S.T. - Virtual Agriculture: Developing and transferring agricultural technology in the 21st century. University of Illinois, www.ag.uiuc.edu/virtagl.html.
- Janowski, T.; Acebedo, C.M. - Virtual Enterprise: On refinement towards an ODP architecture, Workshop on Theoretical Problems on Manufacturing Design and Control, Costa da Caparica, Portugal, Jun 1996.
- NIIIP - The NIIIP Reference Architecture (Revision 6), Jan 1996, www.niiip.org.
- Rabelo, R.; Camarinha-Matos, L.M. - Towards agile scheduling in extended enterprise, in *Balanced Automation Systems II: Implementation challenges for anthropocentric manufacturing*, Chapman & Hall, Jun 1996.
- SCM+ - SCM+: Beyond Supply Chain Management - Technical Annex, INCO-DC Programme, Sept 1995.
- Walton, J.; Whicker, L. - Virtual Enterprise: Myth & Reality, *J. Control*, Oct 96.