*II International Conference on Industrial Engineering and Industrial Management*
*XII Congreso de Ingeniería de Organización*
*September 3-5, 2008, Burgos, Spain*

# An application to support the supply chain collaborative planning process under temporal and spatial integration[81]

**Mª del Mar Alemany[1], Jorge Juan Boj[2], Faustino Alarcón[3], Francisco Cruz Lario[4]**

[1, 2, 3, 4] Centro de Investigación en Gestión e Ingeniería de la Producción (CIGIP), Universidad Politécnica de Valencia, Camino de Vera s/n, Valencia 46022. [1]mareva@omp.upv.es, [2]jorbojvi@upvnet.upv.es

## Abstract

*The present paper shows the developed application with the aim of supporting the collaborative planning decision-making process of a generic supply chain (SC CP). The application allows defining various temporal decision levels (temporal integration). Furthermore, for each temporal decision level it is possible to define both a centralized decision-making (just one decisional centre (DC)) and a distributed decision-making (several DC's), being necessary for this last case to deal with the spatial integration. The application collects the relevant information about the different views (physical, organization, decision, function and information views) describing the SC CP process, with the aim of supporting the model-maker to develop the corresponding mathematical programming models of each DC identified in the supply chain. Then, the resolution of each DC mathematical programming model can be solved in the sequence defined trough the function view simulating the real decision making process.*

**Keywords:** Collaborative Planning, Supply Chain, Mathematical Programming Models, Application

## 1. Introduction

Supply Chain Management (SCM) is concerned with the coordination of material, information and financial flows within and across legally separated organizational units (Christopher, 1998). One important way to achieve coordination in an inter-organizational Supply Chain (SC) is the alignment of the future activities of the SC members. In general, a SC faces the problem of information asymmetry, members having their own objectives and constraints which may be in conflict with those of the other members. Still, activities have to be aligned in such way that the SC as a whole stays or becomes competitive while each member wins by cooperating.

During the last years numerous works (Tapia and Roca, 2002; Akintoye et al., 2000; Callioni and Billington, 2001; Stadtler and Kilger, 2002; Heikkilä, 2002 and Albino et al. 2002) have

[81] This work stems from the participation of the authors in a research project funded by Ministerio de Educación y Ciencia, reference PDI2004-06916-C02-01, titled "Metodología Jerárquica en contexto de Incertidumbre en la Planificación Colaborativa de la Cadena/Red de Suministro-Distribución. Aplicación al Sector Cerámico".

revealed that one of the approach that can help the enterprises to face better the current problems of the Global Market is the Supply Chain Collaborative Planning (SC CP) approach: it proposes to solve in a coordinated manner the problems with regard to parents of the SC where all of them get favoured.

The Collaborative Planning (CP) can be defined as "an interactive process in which both customers and suppliers of a value chain collaborate continuously sharing information about demand for jointly planning their activities" (Alarcón et al., 2006). SC CP goes beyond mere exchanging and integrating information among the partners of the SC and involves strategic and tactical joint decision making among the members in different management areas. The result of a CP is not only the reduction of waste in the SC, but reduced stock levels, eliminated redundant activities, increased the availability of the products, increased of the sales, knowledge of the order cycle, increased of the customers' satisfaction and creation of synergies among all the members of the partnership (Alarcón et al., 2004). Although, different authors have identified several costs and difficulties in the CP. In his research, Nesheim (2001) mentions that the cooperation relationships have a cost and the companies must establish collaborative relationships when the collaboration's profits are higher than their costs. The author Heikkilä (2001) indicates that the strategic relationships create new value but they are costly to develop, support and maintain and special investments are required. Also, Kim (2000) makes reference to the fact that the manufacturer must convince to the supplier that it is worth the collaborative relationship for both partners. Finally, Chopra and Meindl (2001) mention that each partner of a SC has different objectives and they can put their own objectives before the common objectives of the SC.

One of the main challenges faced by the CP is to tackle simultaneously the spatial integration (i.e. coordinating the decision-making across various functions in a company or across various geographically distributed organizations) and temporal integration (e.g. coordination of decisions across different timescales) (Grossmann, 2005).

Spatial integration can be achieved in either a centralized or decentralized (distributed) way. In a centralized decision-making process, a single planner or organization is acquainted with all system information. The planner has the authority to manage associated operations or processes of all entities within the network, determines the optimal level of the collection amount from the source and seeks the optimal solution (the maximum profit) for the entire system. In a decentralized decision-making process the SC is considered as a several independent entities individually operated by self-interested parties who are unwilling to reveal their own confidential information for processing capacities or cost structures to others or the public. Each independent entity has its own profit function which is subject to its constraints. In addition, the decision variables for each entity are often influenced by other entities' decision, coupling prices between members of the same tier, and flows between SC tiers. (Hong et al., 2006)

Pibernik and Sucky (2007) point out that while centralized decision-making achieves better results that the decentralized one, there are two major impediments to implement the centralized option: the necessary alignment of individual decisions to SC-wide objectives and the SC-wide information sharing. One of the most important differences between the two approaches is the system robustness. In a centralized system, failure of the centralized coordinator can potentially cause catastrophic failure of the whole system. On the other hand, decentralized system tends to be more robust to failure (Anderson, 2000). There are occasions when the centralized approach may be favoured over the decentralized approach. The centralized decision-making is usually favoured when industry faces some complex but static problem (Bonabeau et al. 1999), for instance, determining the best locations for a set of facilities. This is because a centralized decision-making process is more likely to find the global solution, and not some local maximum. When the problem is dynamic then decentralized decision making process may be favoured, especially when reconfiguration costs are low. Dynamic problems are typical for industry in the face of varying customer orders, worker absenteeism, machine breakdown, etc. Decentralized decision-making process necessarily makes continuous adjustments to track the optimal solution. So, when reconfiguration costs are low than the real time changes and improvements afforded by a decentralized approach are likely to be favoured.

The present paper shows the application developed with the aim of supporting the CP decision-making process of a generic SC composed by several DCs belonging to different temporal levels. The decision making-process of each DC is supported by means mathematical programming models. The application allows defining various temporal decision levels (temporal integration). Furthermore, for each temporal decision level it is possible to define both a centralized decision-making (just one Decisional Centre (DC)) and a distributed decision-making (several DC's) being necessary for this last case to deal with the spatial integration. The developed application collects the relevant information about the different views (Physical, Organization, Decision, Function and Information Views) describing the SC CP process, with the aim of supporting the model-maker to develop the corresponding mathematical programming models of each Decisional Centre (DC) identified in the SC. Then, the resolution of each DC mathematical programming model can be solved in the real sequence defined in the CP Process and collected trough the Function View.

The paper is structured as follows: Section 2 defines the SC through the different mentioned views. Section 3 shows the structure of the developed application. Section 4 depicts the structure of a generic mathematical programming model associated with a generic DC. Section 5 shows the outputs of the application. Finally, Section 6 states some conclusions of the developed work.

## 2. Supply Chain Description through Different Views

The CP Process is mainly considered as a decision-making process, since the most of the activities of this process have a decisional nature. As CP decisions are made in a predetermined sequence (function view) on elements as physical and human resources, items, etc. (physical view), which are arranged into a specific way (organization view) and it is needed a specific information (information view), to properly model the CP process, firstly it is needed to describe the different views, and next to establish the relationships among the elements belong to each view.

The developed application has been designed following the terminology defined in the framework for the modelling of the SC CP process proposed in Alarcón et al. (2007). The present framework has been elaborated within the scope of the mentioned CICYT Project and it carries out the methodology for the decisional analytic modelling under a deterministic context of the SC CP process. This methodology provides to the application's user a guideline to develop mathematical programming models for the SC CP process in a context of spatial and temporal hierarchy.

Next, it is shown a brief outline of each considered view, describing the different elements which define each view and the relationships among them and also with the elements that belong to other view.

- **Physical View**: this view analyzes the configuration of a particular SC, the existed resources, how theses resources are physically connected and which items (raw materials, components o final products) flow among them. It is considered that a generic SC is composed by four stages: supplier, procurement, production and distribution. In each stage are identified a series of nodes (physically separated facilities which carry out one or more planning functions). The nodes are linked by arcs, which represent external logistics activities, that is, procurement (input arcs) and distribution (output arcs). To plan the operations of a SC will be necessary to know some information about the nodes, arcs and items that flow through them. This information will be collected in the information view.

- **Organization View**: it represents the structure and relationships among the resources shown in the physical view. This view is divided into two different sub-views: micro organization sub-view (how each node is arranged internally) and macro organization sub-view (how the different nodes of each stage are arranged among them). In concordance with the scope of SC CP, the methodology establishes two organizational levels: tactical and operational**.** At each level, there will be one or more organizational centres and at the macro sub-view it may be one or more inter-organizational centres, which take care of various organizational centres. To conclude the definition of this view is needed to establish the relationships of interdependence among the organizational centres belonging to the same organizational level (spatial hierarchy) or among organizational centres belonging to different organizational levels (temporal hierarchy).

- **Decision View**: this view is very closely related with the organization View. The reason is that the SC CP decision-making process depends on the way the different resources of the physical view are arranged in the organization view and it also depends on the spatial and temporal hierarchies among the organizational and inter-organizational centres. Just like the organization view, the decision view is also divided into two sub-views: macro-decision view (in which are specified the considered decisional centres, the features of the interdependence relationships among them, the temporal specifications of the planning and the decision activities) and micro-decision view (which characterized the decision-making process of each decisional centre by means of mathematical programming models). It is considered that an organizational or inter-organizational centre becomes a decisional centre as long as this centre makes decisions, whether they are made in an automatic way or not, which affect the planning function (procurement, production, storage and distribution). Once the DCs have been identified and assigned the corresponding decisional level (tactical or operational) it is time to establish the spatial (among DCs in the same decisional level) and temporal (among DCs in different decisional levels) hierarchies among the DCs.

- **Function View:** this view makes reference to the modelling of the processes. A Process Model must contain the basic information which answers the following questions: What to do, how and when to do it. Although, a functional model can also answer the next questions: who do it, what resources and information with, what is it obtained. These questions related the Function View with the rest of the views.

- **Information View**: this view makes reference to the representation of the required information to define each of the previous view and also the information which must be considered in the CP Decision-Making Process.

The previous views are not isolated elements without any relationship among them, since there is integration among them because common information is share for several views. Figure 1 shows the relationships among the different elements of each view.

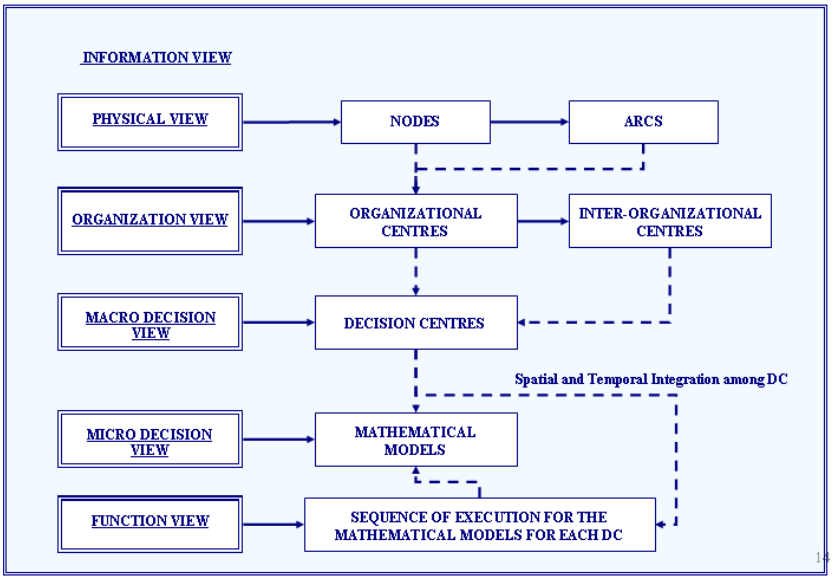


**Figure 1**. Integration of the different SC CP views

The elements of the Physical View that have been taken into account in the application are: nodes, arcs and the relationships among them. The organization of these modes and arcs are responsibility of specific Organizational e Inter-Organizational Centres which are defined in the Organization View, jointly with the relationships among them. The Decisional Centres transmit their decisions for further execution to the Organizational e Inter-Organizational Centres. Therefore, as shown in the Figure 1, a specific Decisional Centre comprises a set of Organizational e Inter-Organizational Centres. One Organizational or Inter-Organizational Centre can become into a Decisional Centre, in the Macro Decision View, whether one of the function of this centre is to make decisions. Through the Macro Decision View, the definition of the DCs, their position at the temporal and spatial hierarchy and their interdependence relationship are defined. Once it has been done, it is time to detail the mathematical programming model to support the decision process at each individual DC. Therefore, at the Micro Decision View the model-maker defines the mathematical model of each Decisional Centre according with the features of its decision-making process and the relationships with the others. Finally, at the Function View, it is established the sequence of execution for the mathematical models of each Decisional Centre depending on the spatial and temporal hierarchies defined among the Decisional Centres.

## 3. The Application Structure

The aim of the application is not to collect all the necessary information to define each of the previous views, identified in the developed framework, but all the relevant information to support the model-maker to develop the corresponding mathematical programming models of each Decisional Centre (DC) identified in the Decision View.

The information compilation for each view is carried out in a friendly and guided way, starting from the most physical level (Physical View) and ending in to the most dynamic level (Function View) of the SC, going through the Organization and Decision Views. In the Figure

2 it is shown the collection sequence of information for the different views and the required details of each one of them.

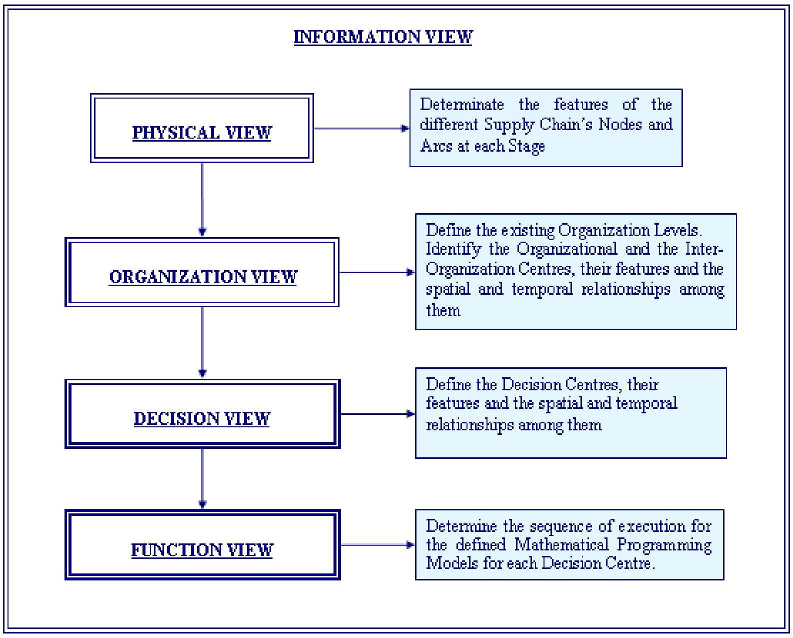


**Figure 2**. The collection sequence of information of the views

The first step, in the introduction of information, is to identify the scope of the methodology, establishing the number of Nodes at each stage, identifying the Arcs which link the Nodes and the corresponding features of the identified Nodes and Arcs. Next, in the second step, the application user must define the existing organizational levels and introduce the number of Organizational and Inter-Organizational Centres placed at each organizational level, their features and the spatial and temporal relationships among them. The Decisional Centres (DCs) are defined from the Organizational and Inter-Organizational Centres, in the Decision View, together with their features and inter-relationships. Finally, at the Function View, it is established the sequence of execution of the defined mathematical programming models for each Decisional Centre extracted from the defined spatial and temporal relationships among DCs. All this information is represented and structured in the Information View and support the model-maker to define the deterministic mathematical programming model of each DC.

## 4. Structure of a Generic Mathematical Programming Model Associated with a Generic DC

The tool supposes that every DC mathematical programming model consists of a definition part (indexes, sets, parameters and data) and a modelling part (objective function and constraints) (Alemany et al., 2007). The application supports the introduction of the information in a friendly and guided way, as shown in the Figure 3. This information is used by the application to automatically generate a text file, with the format of the MPL programme, for the definition part of the mathematical programming model of each DC. The model-maker must complete the modelling part introducing the objective function of the model and its constraints, using the MPL language.

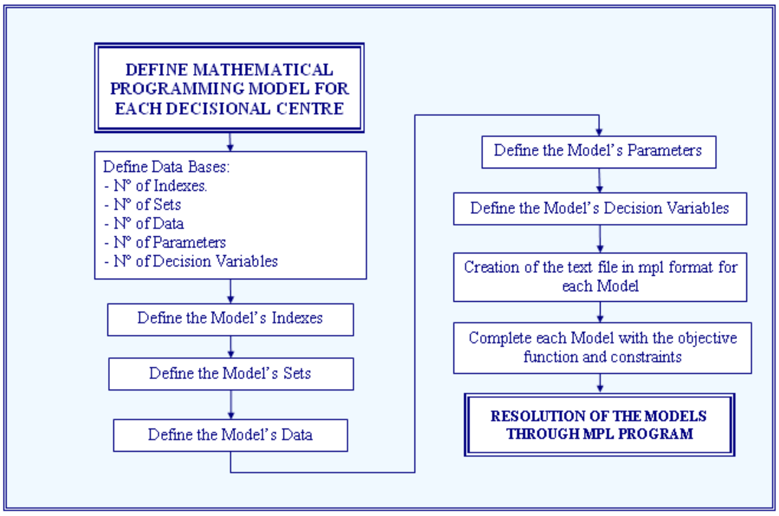


**Figure 3**. Definition Sequence for a Generic Mathematical Programming Model of a Generic DC

The application uses the MPL programme to solve the defined mathematical programming models for each DCs following the sequence established in the Function View. Once a DC mathematical programming model is executed, its decision variables values and the objective function value are stored in a database created by the tool.

The existence of spatial and temporal hierarchies among the DCs involves that the DCs share information among them. But the CP decisions are made in the presence of incomplete information, since the companies that belong to a SC generally unwilling to disclose all their information (Poundarikapuram, 2004). For that reason no partner of a SC has not complete knowledge about the constraints and objectives of other partners or the system as a whole. However, the application takes into account this fact and allows the user leaking the necessary information from the decision variables values (output) of one model as values of parameters (input) of another model, as shown in the Figure 4.

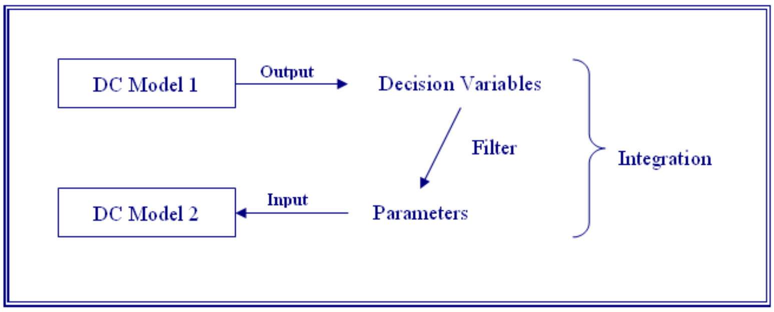


**Figure 4.** Information integration between mathematical programming models

## 5. Outputs of the Application

At the end of the execution the application creates two output files: a database and a text file (Figure 5). The database hosts all the introduced information and it is divided in two different groups, one of them makes reference to the information that describes the Physical, Organization, Decision and Function Views. The other group refers to the required data to solve the mathematical programming model corresponding to a DC. The database contains all data of every defined mathematical programming model to support the spatial and the temporal integration.

The application generates a text file with the corresponding syntax to run by the MPL programme. The user only have to complete the sections refer to *macro* (which represents mathematical expressions), *model* (which represents the objective function), *subject to* (which represents the constraints of the model) and *bounds* (which represents the limit values of the decision variables, if they exist) using the corresponding syntax. The introduction of this information can be done using the text editor incorporated into the application. The rest of the sections of the text file are filled automatically defining the connection with the database, which is represented by the discontinuous line between the text file and the mathematical programming model in the figure 5.

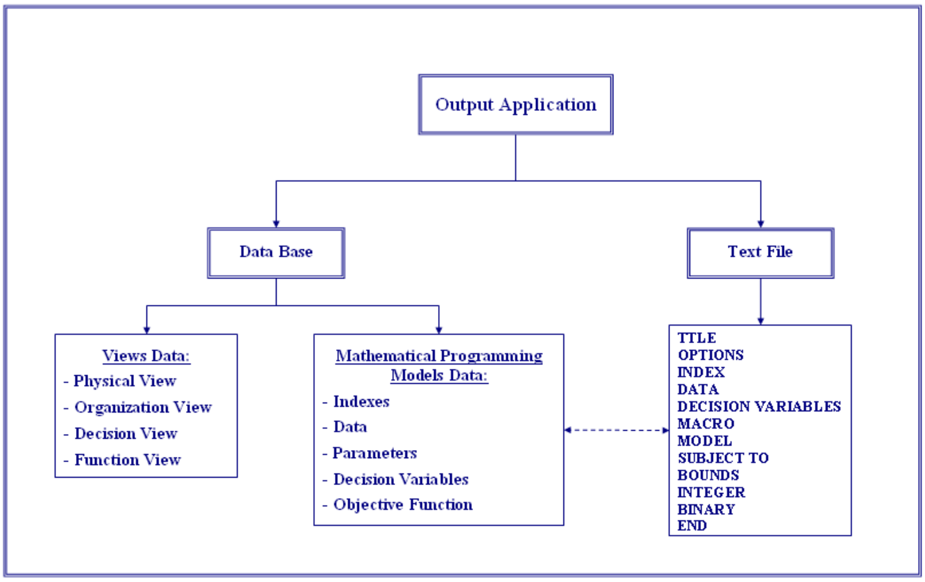


**Figure 5.** Outcomes of the Application

## 6. Conclusions

The aim of the presented application is to support the development and execution of mathematical programming models that support the decision-making in the CP process within a generic SC. The developed application allows the decision-maker:

- Define and design a SC through the Physical, Organization, Decision, Function and Information View.
- Analyze the decision-making process at each DC, creating the corresponding mathematical programming model.
- Solve all the designed mathematical programming models to analyze the outcomes of the CP process in a generic SC.

The application can also be used to solve an independent mathematical programming model without the need to be connected with a DC. In this case the application also creates the corresponding database and the text file to support the introduction of data and to show the obtained outcomes.

The main contribution of the developed application is to make possible both the spatial and the temporal integration simultaneously, in a context of either centralized or distributed decision-making. Furthermore, the tool can be used as a simulating tool in order to test the impact of different coordination mechanisms among DCs, redefining either the information flows (decision variables of a DC that are transmitted as input parameters to other DCs), or the sequence of the execution of the DCs mathematical models.

Furthermore, the application allows the simulation of hybrid form of coordination between the centralized and decentralized decision-making process: the ''partially centralized SCMP'' (Pibernik, 2007). In this approach, it is possible to consider an inter-domain planning approach, in which a subset of individual planning domains agree on centralized master planning with the aim to improve horizontal and vertical coordination within the (sub-) networks for which these domains are responsible. In this sense, the developed application can support the evaluation of different decision configuration for the SC with different decentralization degree that represent one or more alternatives to coordinate the master planning decisions which can be acceptable for the partners involved. Based on the results of this evaluation a selection of the best decision configuration among those tested can be made to improve the SC efficiency.

**References**

Akintoye, A.; McIntosh, G.; Fitzgerald, E. (2000). "A survey of supply chain collaboration and management in the UK construction industry". *European Journal of Purchasing Management*, 6:159-168.

Alarcón, F.; Ortiz.A.; Alemany, MME.; Lario, Fco.C. (2004). "Planificación colaborativa en un contexto de varias cadenas de suministro: ventajas y desventajas". *VIII Congreso de Ingeniería de Organización*. Leganés (Madrid).

Alarcón, F., Alemany, M.M., Ortiz, A., y Lario, F.C. (2006), "Modelling the Order Promising Process for Collaborative Networks", en *ECPPM (European Conference on Product and Process Modelling)*, VI ed., Valencia.

Alarcón, F.; Lario Fco. C.; Bozá, A.; Pérez, D. (2007). "Propuesta de marco conceptual para el modelado del proceso de planificación colaborativa de operaciones en contextos de redes de suministro/distribución (RdS/D)". *XI Congreso de Ingeniería de Organización*. Madrid.

Alemany, MME.; Pérez D.; Alarcón, F.; Ortiz.; Boza A. (2007). "Planificación colaborativa en cadenas de suministro mediante programación matemática en entornos distribuidos". *International Conference on Industrial Engineering and Industrial Management*. Madrid.

Albino, V.; Izzo, C.; Kühtz, S. (2002). "Input-output models for the analysis of a local/global supply chain". *International Journal of Production Economics*, 78:119-131.

Anderson, C.; Bartholdi, J.J (2000). "Centralized versus decentralized control in manufacturing: lessons from social insects". *Complexity and Complex Systems in Industry.*

*Proceedings*, University of Warwick, 19th–20th September 2000, (McCarthy, I. P. and Rakotobe-Joel, T., Eds.). The University of Warwick, U.K. 652 pp. [ISBN 0 902683 50 0].

Bonabeau, E.; Dorigo, M.;Théraulaz, G. (1999). *Swarm Intelligence: From Natural to Artificial Systems*. Santa Fe Institute on the Sciences of Complexity. Oxford University Press, New York.

Callioni, G.; Billington, C. (2001). *Effective collaboration. OR/MS Today*. http://lionhrtpub.com /orms/orms-10-01/ callioni-bilingtonfr.html.

Chopra, S.; Meindl, P. (2001). *Supply chain Management*. Prentice Hall, Chapter 2 and 5.

Christopher, M. (1998). *Logistics and Supply Chain Management, Strategies for Reducing Cost and Improving Service*. 2nd edn. Financial Times Pitman Publishing, London.

Heikkilä, J. (2002). "From supply to demand chain management: efficiency and customer satisfaction". *Journal of Operations Management*, 20:747-767.

Hong, I.H.; Ammons, J.C.; Realff, M.J. (2008). "Centralized versus Decentralized Decision-Making for Recycled Material Flows". *Environmental Science & Technology*, 42(4):1172-1177.

Kim, B. (2000). "Coordinating an Innovation in Supply Chain Management". *European Journal of Operational Research*, 123:568-584.

Nesheim, T. (2001). "Externalization of the core: antecedents of collaborative relationships with suppliers". *European Journal of Purchasing & Supply Management*, 7:217-225.

Pibernik, R.; Sucky, E. (2007). "An Approach to Inter-Domain Master Planning in Supply Chains". *International Journal of Production Economics*, 108:200-212.

Poundarikapuram, S.; Veeramani, D. (2004). "Distributed Decision-Making in Supply Chains and Private E-Marketplaces". *Production and Operations Management*, 13(1):111-121.

Stadtler, H.; Kilger, C. (2002). *Supply Chain Management and Advanced Planning*. Springer.

Tapia, C.; Roca, E. (2002). *Planificación integrada de la demanda*. http://www.redesde colaboracion.com/p_planificacion/index.htm.