Collaborative model for customer request ordering: research and selection of substitute suppliers

Smaïl Khouider, Thibaud Monteiro, Marie-Claude Portmann

COLLABORATIVE MODEL FOR CUSTOMER REQUEST ORDERING: RESEARCH AND SELECTION OF SUBSTITUTE SUPPLIERS.

Khouider Smaïl[+], Monteiro Thibaud[+] and Portmann Marie-Claude*
MACSI project/INRIA
E-mail: Khouider@univ-metz.fr ; {thibaud.monteiro; Marie-Claude.Portmann}@loria.fr
[+] LGIPM, Université Paul Verlaine de Metz, Ile du Saulcy 57012 METZ cedex 01, France
* LORIA-INPL, École des Mines de Nancy, Parc de Saurupt, 54000 Nancy Cedex, France

Abstract: In this paper, we propose supplier research protocol and decision tools for supplier selection. The architecture of the negotiation and decision making is supported by a multi agent system and uses mixed integer programming models and solvers. The supply chain is composed by autonomous enterprises. Each enterprise must reach, in the same time, local and global goals. The research protocol is implemented in a virtual agent "Tier Negotiator Agent (TNA)" implanted in each tier of the supply chain, which provides human decision makers with data tables and suggests them to follow some directives. One TNA is activated each time a customer does not find sufficiently components for covering its needs and the protocol can activate TNA of upstream tiers.

Keywords: Supply Chain Management, Collaboration, Substitute Suppliers, Multi Agent System, Supply Chain Architecture.

1 Introduction

The interest of Supply Chain Management (SCM) problems increases recently, due to quick and incontrollable change in enterprise background. Enterprises must maintain there position in the market-place. The networked organisation rises for acquiring stability in enterprise relationships often in perpetual modification.

Conceptual studies on supply chain management have emphasized the importance of the strategic relationships between companies. These relationships aim to increase financial and operational performance of these companies by reductions in the total cost and inventories throughout the supply chain; in consequence, the levels of shared information increase significantly (Türky, et al., 2004).

The decision making in the networked organisation is a complex process, because any companies make local decisions and cannot control their effects in suppliers channel, see (Biswas and Narahari, 2004). One of the important problems in the SCM is harmonising all decisions of supply chain partners. The basic purpose of supply chain coordination is to devise a mechanism that will induce the retailer to order the right quantity of products and set the right retail price so that the total profit of the supply chain is maximized (Qi, et al.; 2004). Many works are attached to develop method and tools for coordinating two or three tiers of supply chain, see (Munson and Rosenblatt, 2001; Despotin-Monsarrat, et al., 2005), in Dudek and Stadtler (Dudek and Stadtler, 2005), collaborative planning is used for negotiation between supply chain partners.

In networked organisation, companies require to order products from other sources (such as suppliers). The problem of how to allocate orders to the proper suppliers tends to be an important topic, especially in case of the multiple suppliers' environments, for more details of selecting suppliers' problem see (Kawtummachai and Van Hop, 2005).

In this paper, we present demand satisfaction problem in a particular context. A company addresses requests to its usual suppliers and waits for their answers. In the best case, their answers are favourable. But there exist situations in which the answers are not suitable. A question arises then: how to react in front of this problem?

We propose, in this paper, a method to research and select suppliers in order to satisfy, if possible, completely the request. In section 2, we develop the general context of this work. In section 3, we describe the induced problems and in section 4, we present the proposed method and a first experimentation on a small example.

2 General context

The supply chain considered in this paper consists in several enterprises autonomous in their decision-making. There do not exist only one decision-making centre, but each company makes its own decision. This is a distributed environment. The companies are ranked by tiers; a company is at a smaller rank (tier number) than its suppliers, see (figure 1).

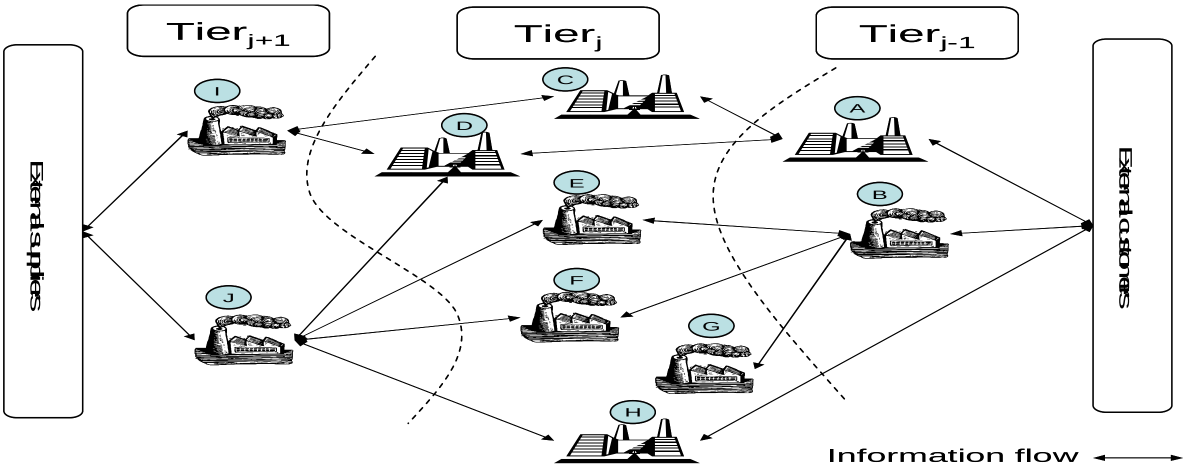

Figure1: Considering supply chain

Relations which govern two companies are based on a collaborative win-win policy (Ouzizi, et al., 2003). Each company’s goal is to maximise its own profit without creating too many difficulties to its supply chain partners.

2.1 Supply chain model

Companies which compose the supply chain are represented by Virtual Enterprise Nodes (VEN) see (Anciaux, et al., 2004, Ouzizi et al, 2005). The VEN is the basic component of our architecture. Relationships between couple of chain partners (suppliers and customers) are located in adjacent tiers, see (figure 2).

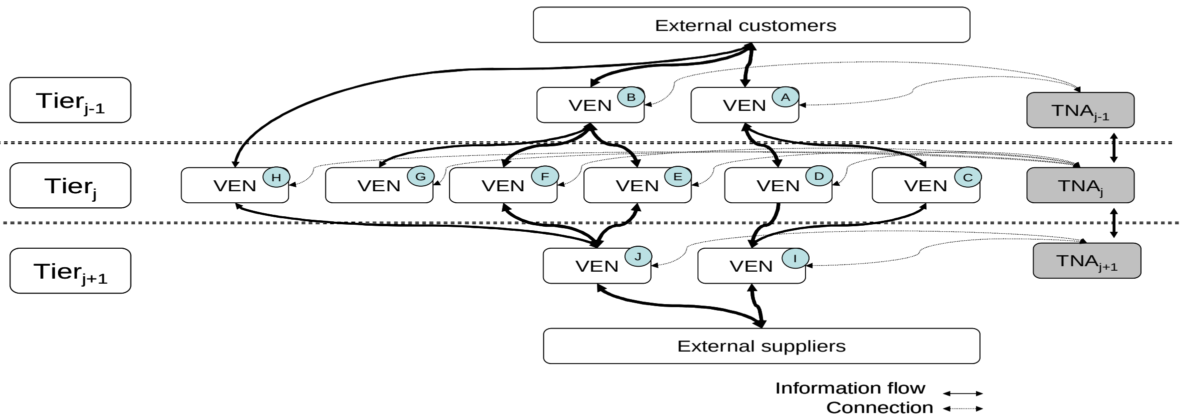

Figure 2: Supply chain architecture

Virtual Enterprise (VE) is a development of the extended enterprise concept. The extended enterprise is presented in (Perrin and Godart, 2004). In the view of Aerts et al. (Aerts, et al., 2002), VE is an ad hoc organisation that joins core competencies and commits its resources to respond to unexpected business opportunities. A large review of VE concept is detailed in (Wu and Su, 2005). Contrary to the extended corporation, the VE characterizes a consortium where each VEN member is totally free for their local decision-making.

2.2 Organization of multi agent architecture

2.3.1 VEN

In our approach, we model VENs using multi agent architecture, see (figure 2). An agent is a combination of reactive software entity and human decision actor, with its own environment and decision-makings tools. But to improve its performance, it collaborates with the other entities existing in its environment; see (Luck, et al., 2004).

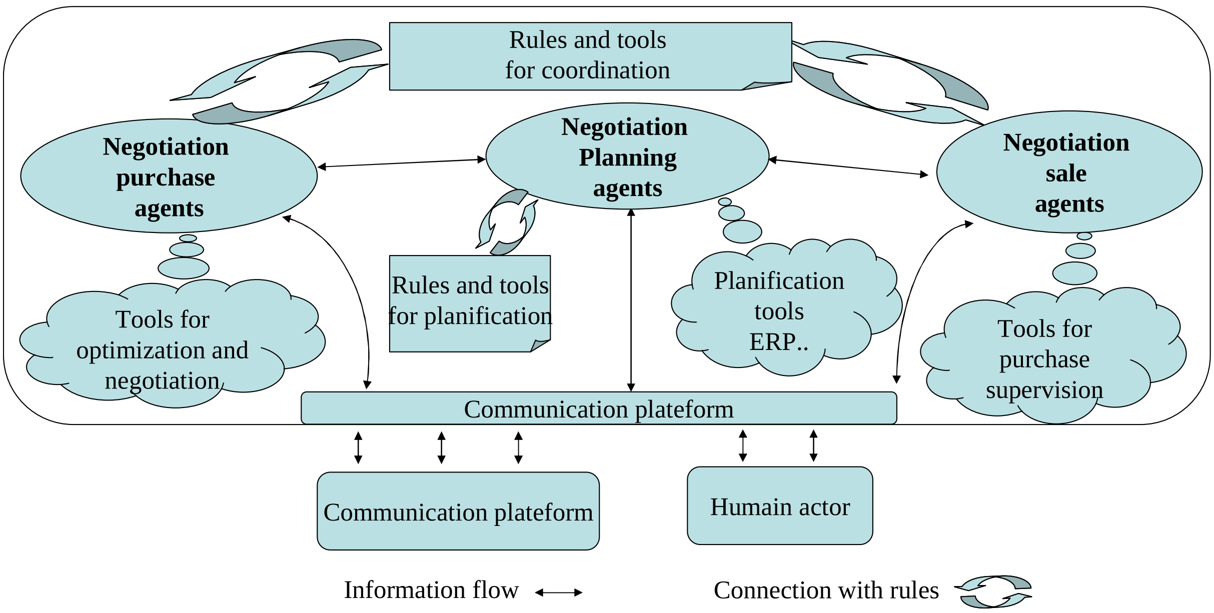

Figure 3: VEN composition

The VEN is composed with three software agents and communication platform, see (figure 3). Each agent collaborates for correct operations linked to production, sale and purchase.

- Negotiation Sale Agent: it manages and negotiates sales. It contacts directly the negotiation planning agent and several external purchase agents (its customers).
- Negotiation Purchase Agent: it manages and negotiates purchases operation. It contacts directly the negotiation planning agent and several external sales agents (its suppliers).
- Negotiation Planning Agent: it manages planning of production. It also provides forecasted planning and finished product availability. It contacts directly the two other VEN agents. It uses either planning software pre-existing in the company or imposes design of planning rules.

2.3.2 TNA

The TNA (Tier Negotiation Agent) is the supervisor of each supply chain tier. The TNA goal is to solve conflicted situations. It receives requests from its tier's VEN and other TNA's. Each TNA needs significant data knowledge from VEN of its tier (figure 2).

3 Problem description

A company corresponding to a given VEN must have a given quantity Q of raw materials or components before beginning each production series at forecasted date t. If Q cannot be delivered entirely before date t by its usual suppliers, the company tries to partition Q into several parts (Q_1, Q_2, Q_3…) requested at dates (D1, D2, D3…) along the production period (tightest Just-In-Time policy).

In fact, for carrying out production planning, internal capacities and availability of raw materials and components (denominated only by components as the general terms in the following) are needed. Requirement of components is a very critical production problem. In consequence reliable suppliers are very important partners. Nevertheless, the shorter products life cycle induces more and more environment changes. Hence, the search and selection of partners external to virtual enterprise become even more difficult.

In our study, we consider the case of a company, which gives orders to its usual suppliers. If their answers cannot satisfy these orders completely, a blocking situation could occur. Indeed, the company cannot start corresponding production at forecasted date, or at least, cannot complete its whole objectives. In this case, several choices can be studied.

- Right shift of the production: This policy is harmful. It creates increase of production costs and/or late deliveries to customers.
- Research of substitute suppliers: A new difficulty arises then: what is the "best" strategy for finding them, for selecting one or several ones and for deciding precise order quantities and due dates? It is the main concern of our work.

These two strategies can be used for solving this problem, but they do not guarantee minimal additional acquisition cost. Consequently we propose a search protocol for finding substitute suppliers using TNA agents as well as a method of selection and adjustment of the confirmed orders.

4 Search protocol and selection method

4.1 Notations

- i : Suppliers index.
- x_i : Equal to 1 if supplier "i" is selected and 0 otherwise.
- Q_t : Quantity of product requested by the company at date "t".
- $q_{i,t}$: Quantity of product delivered by the supplier "i" at date "t".
- c_i : Unit cost proposed by supplier "i".
- CD : Unit Cost desired by the company.
- QD : Total Quantity of product requested by the company.
- λ : Upper bound for the accepted percentage of over cost.
- QR_t : Potential company reception capacity at date "t".

- QS_t : Potential company storage capacity at date "t".
- ΔQR_t : Additional reception capacity associated to one additional resource (manpower or machine) at date "t".
- ΔQS_t : Additional storage capacity associated to one additional resource (warehouse or vacant place unit) at date "t".
- y_t : Unknown numbers of additional reception capacity of size ΔQR_t.
- z_t : Unknown numbers of additional storage capacity of size ΔQS_t.
- CR_t : Cost of ΔQR_t additional reception capacity.
- CS_t : Cost of ΔQS_t additional storage capacity.
- $Cumq_{i,t}$: Cumulated quantity proposed by a supplier "i" until date "t".
- $CumQ_t$: Cumulated quantity requested by the company until date "t".

4.2 Research protocol

A company "i" is represented by $VEN_{i,j-1}$ which is on tier "j-1". It requested components to its usual suppliers which are in tier "j". We assume that a blocking situation occurs like described in section 3.

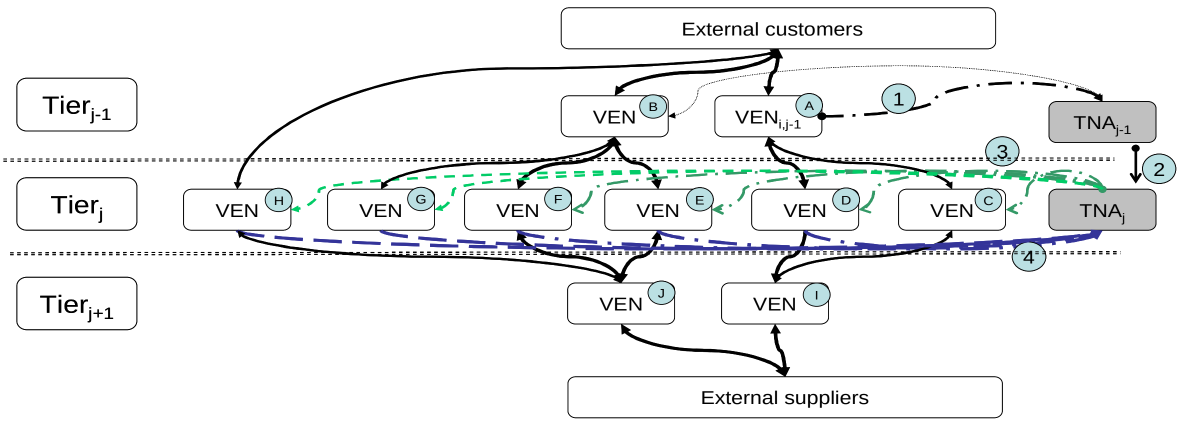

Figure 4: Seek protocol

To tackle with this lack of components, the following protocol is applied:

1. $VEN_{i,j-1}$ contacts the TNA_{j-1} agent (figure 4; #1) of its tier to get help for searching new supplier capacities.
2. TNA_{j-1} transmits this request to the TNA_j (figure 4; #2).
3. TNA_j transmits the same request to all VEN of its tier (figure 4; #3) and waits for answers (figure 5; #4).

TNA_j repeats at most "NRV" times a revival procedure every "Tmax" time until each VEN has given an answer. At the end of the answer collection, the selection algorithm can begin.

4.3 Selection algorithm

The answers received by the TNA_j has the form of a vector containing two series of data (proposed delivery quantity, corresponding proposed delivery dates) completed by the unit cost of each component: (<<Q1,D1>, < Q2, D2 >..., C >). For each answer, a cumulated curve of potential component arrival is computed. All the VEN's cumulated curves are also cumulated, which gives a maximal cumulated curve of potential component arrival.

4.3.1 Request feasibility

The feasibility of the whole set of answers is verified by equation (E1), which compares the maximal cumulated curve of potential arrival with the needed cumulative curve:

$$\forall t : \sum_i Cumq_{i,t} \geq CumQ_i \qquad \text{(E.1)}$$

- If equation E.1 is verified, we can apply the optimization step for selecting the suppliers and adjusting the quantities to be actually ordered.
- If equation E.1 is not verified, TNA_j sends the cumulated curves to the TNA_{j-1}, which transmits them to $VEN_{i,j-1}$. In this case, $VEN_{i,j-1}$ has to decide what to order, knowing it will probably be obliged to re-plan its production to take into account the lack of quantities and/or the tardiness of some deliveries.

4.3.2 Optimization model

The optimization part consists in selecting the potential suppliers to provide the components. This operation is based on the mixed linear programming "π". "π"minimizes the total costs of acquisition of the demand, while respecting quantities and dates of request.

$$\begin{cases} \text{The objective function:} \\ \quad Z = Min(\sum_i CF_i x_i) \quad \text{Where } CF_i = \sum_t c_i q_{i,t} \,. \\ \text{Under constrains} \\ \quad \forall t : \sum_i Cumq_{i,t} x_i \geq CumQ_t \qquad \text{(E.2)} \\ \quad \forall t : \sum_i q_{i,t} x_i \leq QR_t \qquad \text{(E.3)} \\ \quad \forall t : \sum_i q_{i,t} x_i \leq CumQ_t + QS_t \qquad \text{(E.4)} \\ \quad x_i \in \{0,1\} \end{cases}$$

(E.2) represents the satisfaction quantity constraints of components at delivery dates. Whereas (E.3) represents the storage capacities availability constraints of $VEN_{i,j-1}$ per time period. Constraints (E.4) are related to component reception capacities. Integer Linear Programming software can be used to solve this problem. Two possible cases occur:

- If there exists an optimal feasible solution computed by TNA_j, it sends this solution to TNA_{j-1} which transmits it to $VEN_{i,j-1}$. The optimization phase finishes. $VEN_{i,j-1}$ is free to effectively confirm its own orders to the new obtained suppliers.
- If there is a no feasible solution, due to reception and/or storage constraints. In this case, the TNA_j can try to determine where and how many reception and/or storage capacities must be acquired in order to make the problem feasible, while minimizing the additional costs.

The π programs become then π_g where additional reception and storage capacities are added per period of time.

Then the objective function becomes:

$$Z = Min(\sum_i (CF_i x_i) + \sum_t (CR_t y_t) + \sum_t (CS_t z_t))$$

Under constrains:

(E.2)

$$\forall t : \sum_i q_{i,t} \leq QR_t + y_t \Delta QR_t \qquad \text{(E.5)}$$

$$\forall t : \sum_i q_{i,t} x_i \leq Q_t + QS_t + z_t \Delta QS_t \qquad \text{(E.6)}$$

$$x_i \in \{0,1\}$$

The relaxation of both types of constraints, related to the reception and storage capacities, assures the existence of feasible solutions. This solution is only a suggestion, because the additional capacities found with π_g could be higher than those the $VEN_{i,j-1}$ can effectively acquire.

4.4 Example

A given $VEN_{i,j-1}$, *A* in figure 2, orders a given component to its usual suppliers *C* and *D*. We assume that a conflict occurs because quantity requested to C and D is not satisfied. So, result, the company can not carry out its production planning and can not satisfy its customers. The components deficiency is summarized in (table 1). Reception (QR_t) and storage (QS_t) capacity of each time period are illustrated in (figure 5). We generated those data randomly between given lower and upper bounds.

Quantity	65	55	130
Lead-time	7	11	23
Cost/unit	15		

Table 1: Components deficiency

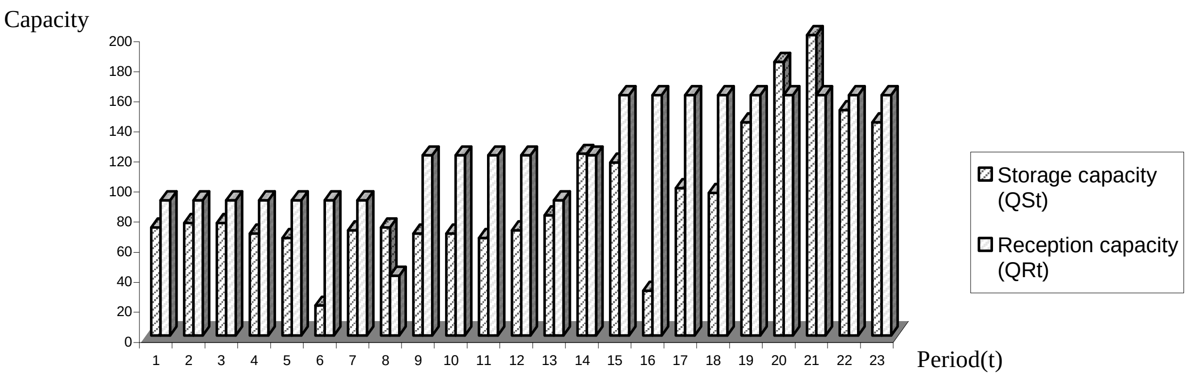

Figure 5: *A's* Capacities data.

$VEN_{i,j-1}$ is assumed to follow the proposed method.

$VEN_{i,j-1}$ sends a request to its TNA_{j-1} for asking help transmitting it its lacks. TNA_{j-1} contacts TNA_j. This one contacts all VENs of its tiers, see (section 4.2).

The suppliers' answers are:

Supplier E	Quantity	10	65	45
	Lead-time	6	8	16
	Cost/unit	15		
Supplier F	Quantity	15	25	75
	Lead-time	7	12	23
	Cost/unit	10		
Supplier G	Quantity	55	25	19
	Lead-time	7	15	25
	Cost/unit	13		
Supplier H	Quantity	135	45	230
	Lead-time	8	11	28
	Cost/unit	16		

Table 2: suppliers' answers

We apply the proposed selection algorithm in order to find the best suppliers, see (section 4.3). The request feasibility is done in the first step. The request and suppliers proposed quantity is shown in (figure 6).

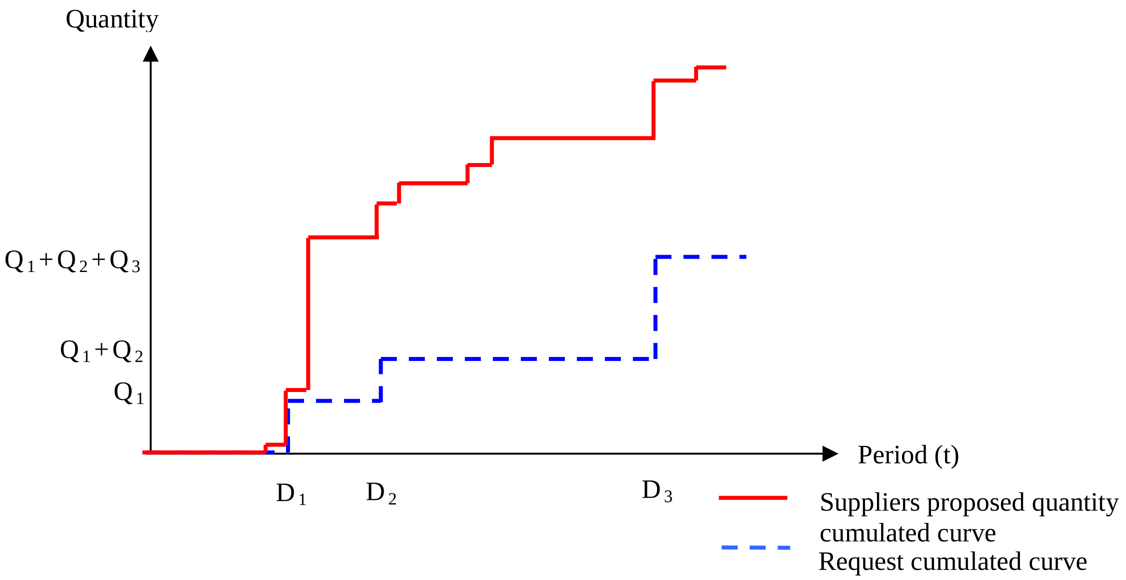

Figure 6: Cumulated curves

For each request period, the proposed quantity is superior to the request quantity. Then, the request feasibility is verified. We can use the second step of algorithm (optimization model), see (section 4.3.2).

The first step of optimization (mixed linear programming "π") phase does not give a feasible solution. Some of the capacity constraints are transgressed. The second step ("π_g") gives a feasible solution with total cost increased by 13%. We resume this result in (table 3) and (figure 7).

Delay	7	11	23	Total quantity	Cost
Request quantity	65	55	130	250	3750
Obtained quantity	80	75	170	315	4403

Table 3: Algorithm result

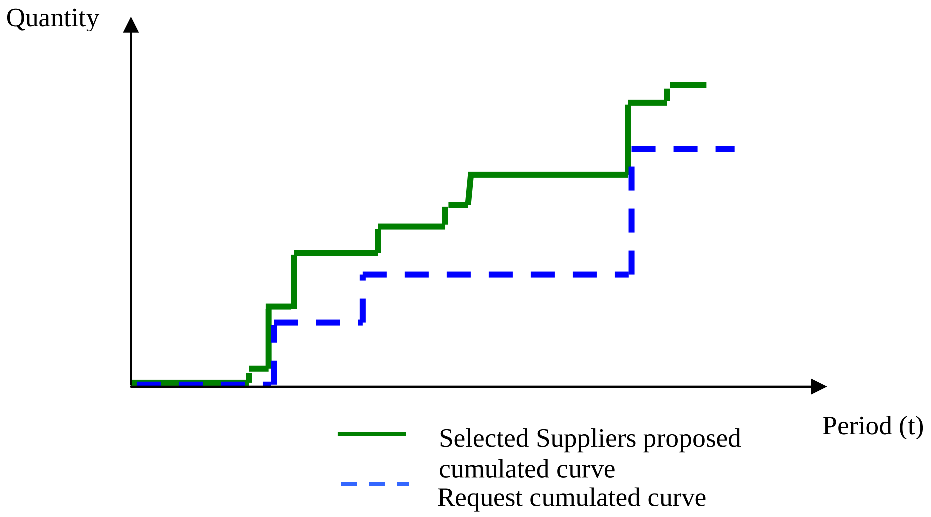

Figure 7: Cumulated curves after selecting

The proposed solution is to select suppliers *E*, *F* and *G* and not to use the proposition of supplier *H*. The added reception capacity (ΔQR_t) is 3 and the added storage capacity (ΔQS_t) is 13.

5 Conclusions and future researches

Order satisfaction problem is the subject of this work. We use multi agent systems to structure the information flow and to place the decision tools. We also have proposed a method for searching and selecting new suppliers. This protocol is supported by TNA agent and a mathematical model. The mathematical model also allows respecting other constraints, such as the capacities of reception and storage of the VEN and to adjust orders to proposals.

The proposed decision tools bring a framework for organizing various protocols inside the supply chain multi agent structure, which can be designed depending on the environment.

When we fail to find feasible solution by adding new suppliers, another decision tools must be designed in order to help the company to re-plan partially its production, to negotiate new delays with its own customers…

For global supply chain management, developments of negotiation and co-operation tools are essential. We will continue to develop efficient tools to organize order decisions.

6 References

Aerts, A.T.M., Szirbik, N.B. and J.B.M. Goossenaerts (2002). A flexible, agent-based ICT architecture for virtual enterprises, *Computers in Industry*, **49**, 311–327.

Anciaux, D., Roy, D. and T. Monteiro (2004). Supply-Chain Management Based on Cost, *IFAC Conference Management and Control of Production and Logistics, Chile.*

Biswas, S. and Y. Narahari(2004). Object oriented modelling and decision support for supply chains, *European Journal of Operational Research*, **153**, 704-726

Despotin-Monsarrat, E, Briand, C. and P. Esquirol. (2005). Aide à la décision pour une coopération interentreprises. *Journal Européen des Systèmes Automatisés*, **39/8**.799-818

Dudek, G. and H. Stadtler (2005). Negotiation-based collaborative planning between supply chains partners, *European Journal of Operational Research*, **163**, 668–687.

Kawtummachai, R. and N. Van Hop (2005). Order allocation in a multiple-supplier environment, *Int. J. Production Economics*, **93-94**, 231-238

Luck, M., McBurney, P. and C. Preist (2004). A Manifesto for Agent Technology: Towards Next Generation Computing, *Autonomous Agents and Multi-Agent Sytems*, **9**, 203–252.

Munson, C. and M. J. Rosenblatt (2001). Coordinating a three-level supply chain with quantity discounts, *IIE Transactions*, **33**, 371-384.

Ouzizi, L., Anciaux, D., Portmann, M.C. and F.Vernadat (2003). A model for co-operative planning using a virtual enterprise. *Proceedings of the 6th international conference on Industrial Engineering and Production Management*, Porto, Portugal.

Ouzizi, L., Anciaux, D., Portmann, M.C. and F.Vernadat (2005). A model for co-operative planning within virtual enterprise. *International Journal of Computer Integrated Manufacturing, Article in press. (Taylor & Francis)*

Perrin O. and C. Godart (2004). A model to support collaborative work in virtual enterprises, *Data & Knowledge Engineering*, **50**, 63-86.

Qi, X., F. Bard, J. and G. Yu (2004). Supply chain coordination with demand disruptions, *Omega*, **32**, 301-312

Türkay, M., Oruç, C., Fujita, K. and T. Asakura(2004). Multi-company collaborative supply chain management with economical and environmental considerations, *Computers and Chemical Engineering*, **28**, 985-992.

Wu, N. and P. Su (2005). Selection of partners in virtual enterprise paradigm, *Robotics and Computer-Integrated Manufacturing*, **21**, 119–131.

7 Biography

Smaïl Khouider, “Ingénieur d’état” in operational research (2001), he prepares his PHD in informatics at University Paul Verlaine. He is mainly interested supply chain management domain and optimization tools.

Thibaud Monteiro received his PHD from Institut National Polytechnique de Grenoble in 2001, and is currently Maître de Conférences at the University Paul Verlaine. His main research interests include supply chain management, performance measurement and collaboration modeling.

Marie-Claude Portmann, "docteur d'état" in applied mathematics (1987), has been Operations Research professor at the Ecole des Mines de Nancy (Institut National Polytechnique de Lorraine, France) since 1988. Her main application domain has been design and control in production manufacturing and more recently decision tools for planning and scheduling the supply chains.