s of collaborative strategies in multi-agent systems: the case of

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1 Thierry Moyaux, Design, simulation and analysis of collaborative strategies in multi-agent systems: the case of supply chain management, phd thesis,

by admin | mai 15, 2008 8:41

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<Abstract>

Une Chaîne logistique est composée d’entreprises fabriquant et distribuant des produits aux consommateurs. En modélisant chacune de ses entreprises comme un agent intelligent, nous étudions l’effet « coup de fouet » qui s’y propage. Cet effet consiste en l’amplification de la variabilité des commandes passées par les entreprises lorsque l’on s’éloigne du client final.

Dans un premier temps, nous modélisons chaque entreprise d’une chaîne logistique forestière québécoise comme un agent intelligent, afin de proposer deux mécanismes de coordination décentralisés réduisant ce phénomène.

Dans un second temps, d’autres simulations sont utilisées pour construire un jeu que nous analysons avec la Théorie des Jeux. Nous vérifions ainsi que les entreprises n’ont pas intérêt d’arrêter unilatéralement d’utiliser nos mécanismes de coordination (équilibre de Nash).

</Abstract>

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<Auteur>

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Endnotes

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6 Comments

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1.1 Chapitre 1 : Introduction

1.1 Stream Fluctuations in distributed Systems: the Bullwhip effect

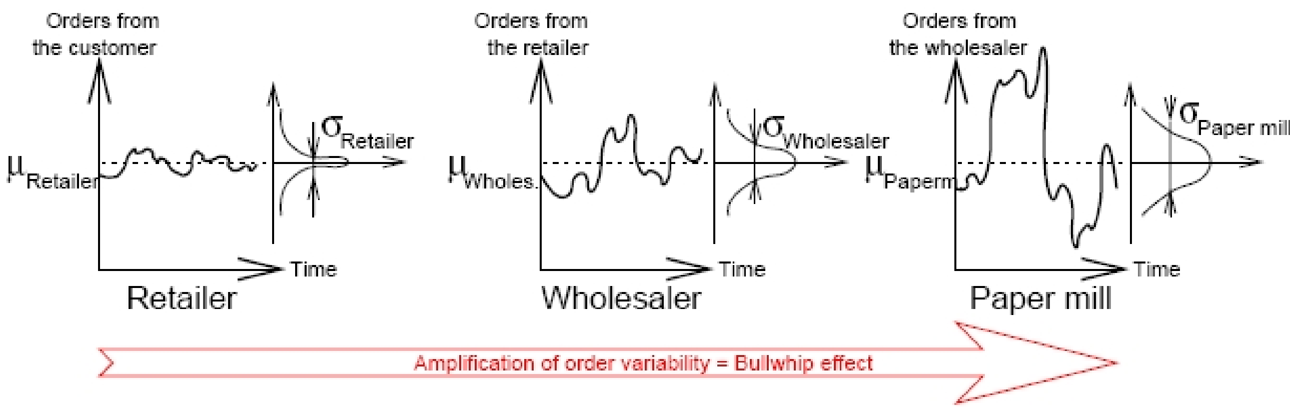

Figure 1.1: The bullwhip effect [Lee et al., 1997a,b].

As a variability, the bullwhip effect is measured by the standard deviation σ of orders (notice that the means μ of orders are all equal in the example of the previous figure).
There are several consequences of the bullwhip effect. In a few words, this effect incurs costs due to higher inventory levels, supply chain agility reduction, decrease of customer service levels, ineffective transportation, missed production schedules… In fact, such fluctuations of the demand lead every participant in the supply chain to stockpile because of high degree of demand uncertainties and variabilities.

1.2 Motivations

To obtain this stabilization, the basic idea is to make all agents' orders conform to the market consumptions. this solution to the bullwhip effet is intuitive, but as we will see later, it does not take opreational constraints into account, i.e. inventories are not well managed.

Principle 1: Lot-for-lot orders eliminate the bullwhip effect, but do not manage inventories.

Principle 2: Companies should react nce (by under or overordering) to each market consumption change.

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1.2 Chapitre 2: Supply Chain Management and Multi-Agent Systems: Background

2.1 Supply Chain Management

The concept of Supply Chain as a solution

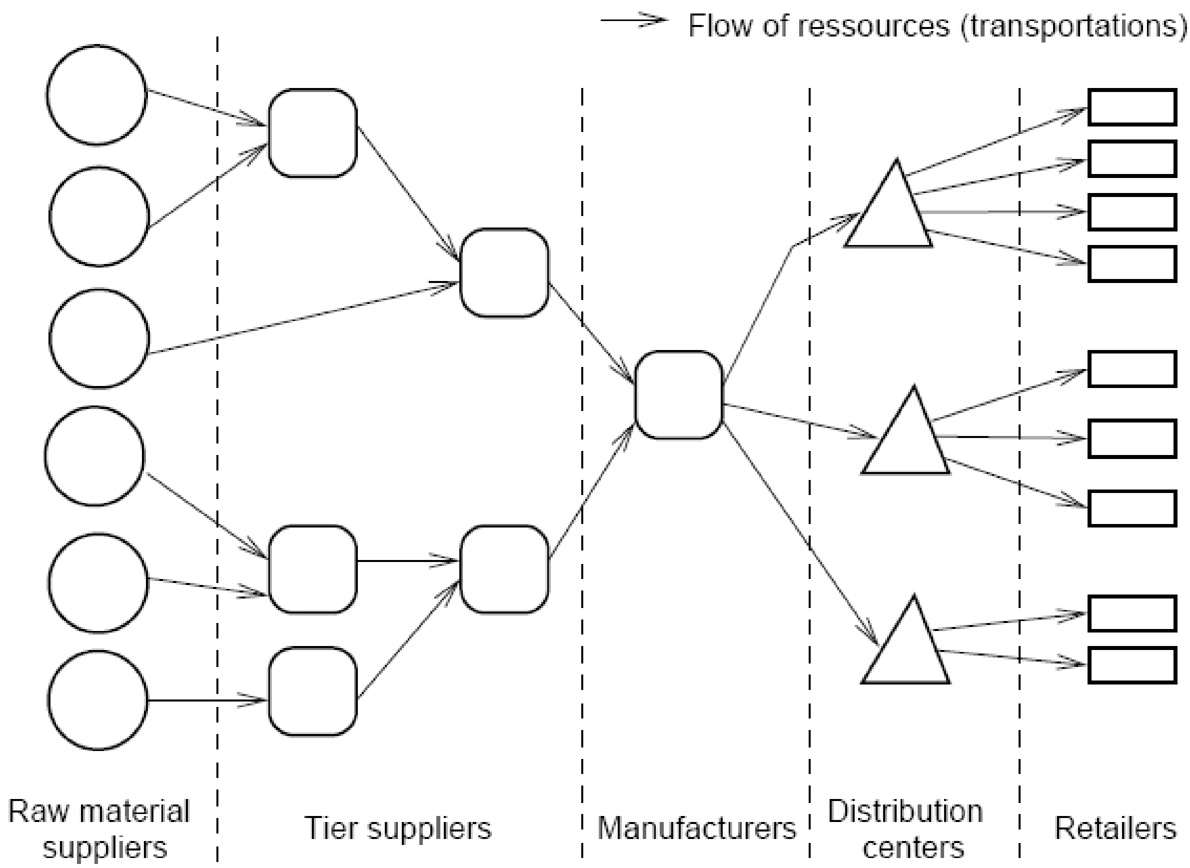

Figure 2.1: A supply chain [Swaminathan et al., 1998; Davidsson and Werstedt, 2002].

(…) these authors defined a supply chain as « the set of firms to design, engineer, market, manufacture, and distribute products and services to end-consumers ». In general, this set of firms is structured as a network, as illustrated in Figure 2.1.

In the same context, Shapiro noted that « supply chain management is a relatively new term that crytallize concepts about integrated business planning that have been espoused by logistics experts, strategists, and operations research practitioners as far back as the 1950s. Similarly Simchi-levi et al. defined this term as a « set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed in the right quantities, to the right locations, and at the right time, in order to minimize systemwide costs, while satisfying service level requirements. Poirier and Reiter noted t\hat the concept of supply chains improves the competitive position of collaborating companies, because it supports the creation of synergies among these companies. In particular, these synergies are due to the fact that a supply chain is a system, and as a consequence, this system is superior to the sum of the consulting companies. as previously explained, the concept of inter-company collaboration is a way to create such synergies in a supply chain.

Collaboration in Supply Chain

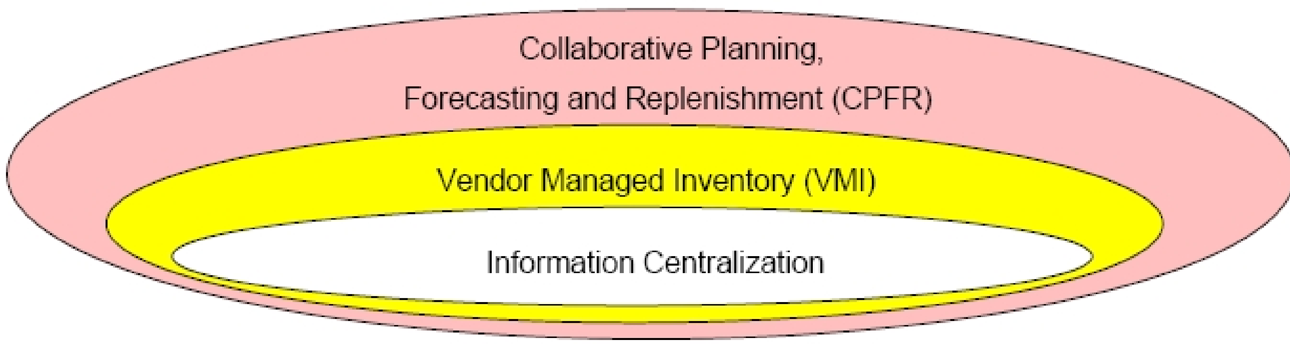

Figure 2.2: Overlap of some collaboration techniques.

Information centralization:
This is the most basic technique of information sharing in which retailers broadcast the market consumption (approximated as their sales) to the rest of the supply chain. (…) It is necessary to distinguish information sharing from information centralization: the latter is a particular case of the former, because information centralization is the multi-casting in real time and instantaneously of the market consumption information., while information sharing is only the sharing of the demand information between any companies, and include thus information centralization.

Vendor Managed Inventory (VMI) and Continous Replenishment Program (CRP):

The idea is that retailers do not need to place orders because wholesalers use information centralization to decide when to replenish them. Although these techniques could be extended to a whole supply chain, current implementations only work between two business partners.

Collaborative Planning, Forecasting and Replenishment (CPFR):
Like VMI and CRP, current implementations of CPFR only include two levels of Supply Chain, i.e. retailers and their wholesalers. With CPFR, companies electronically exchange a series of written comments and supporting data which includes past sales trends, scheduled promotions, and forecasts. This allows the participants to coordinate joint forecasts by focusing on differences in forecasts. Companies try to find the cause of such differences and agree on joint, improved forecasts. They also jointly define plans to follow when specific contingencies occur.

The EOQ Model
D= demand rate (unit per year).
P= production rate (unit per year).
A= fixed cost of a replenishment order ($ per order).
C= unit variable cost of a production (or purchase).
h= inventory carrying cost ($ per unit per year).
π= shortage cost per unit short, independent of the duration of the shortage ($ per unit short).

$\hat{\pi}$= shortage cst ($ per unit short per year).
τ= replenishment lead time, the time between the placement and receipt of an order (years).
Q= order quantity (unit per order).
s= reorder point, i.e inventory level at which an order is placed (units in inventory).
$I_m ax$= maximum on-hand inventory level (units in inventory).
b= maximum on-hand inventory level (units in inventory).
T= cycle length, i.e., the length of time between placement (or receipt) of replenishment orders (years).
K= average annual cost which is a function of the inventory policy ($).

When a ship\ping arrives, inventory position increases at a rate $P - D$ during T_1 and T_2. When production has finished inventory position stops increasing and starts decreasing at a rate D during T_3 and T_4.
Inventory carrying costs are incurred in T_2 and T_3, while backorder costs are incurred in T_1 and T_4. The decision variable are the order quantity Q and the maximum backorder level b. The average cost per cycle is the sum of the procurement, inventory, and shortage costs during the cycle.

There are D/Q identical cycles in a year, because there are lesser placed orders, and thus, lesser cycles, when the quantity ordered Q increases.
The average annual cost K of the considered inventory system is the multiplication of the average cost per cycle by the number of cycles D/Q :

$$K(Q,b) = \frac{AD}{Q} + CD + \frac{h[Q(1-D/P)-b]^2}{2Q(1-D/P)} + \frac{\hat{\pi}b^2}{2Q(1-D/P)} + \frac{\pi b D}{Q}$$

where:

$\frac{AD}{Q}$ = annual ordering cost

CD = annual production (or purchase) cost

$\frac{h[Q(1-D/P)-b]^2}{2Q(1-D/P)}$ = annual inventory carrying cost

$\frac{\hat{\pi}b^2}{2Q(1-D/P)}$ = annual shortage cost

$\frac{\pi b D}{Q}$ = cost of having some backorder during the year

the decision variable Q and b are set up by soplving the two simultaneous equations given by:

$$\partial K/\partial Q = \partial K/\partial b = 0$$

General solutions to this problem are given in following Equations:

$$Q\prime = \sqrt{\frac{2AD}{h(1-D/P)} - (\pi D)^2/h(h+\hat{\pi})}\sqrt{\frac{h+\hat{\pi}}{\hat{\pi}}}$$
$$h\prime = (hQ\prime - \pi D)(1-D/P)/h + \pi$$

Finally, this model is used to set optimal parameters s and S in a (s, S) ordering policy (i.e when inventory level x falls below s, the company orders (S-x):
$S = s + Q\prime$ where x is given by following Equation (note t\hat $m = [\tau/T]$, where [x] is the integer part of x e.g [1,9]=1

$$s = \begin{cases} \tau D - mQ - b & if \tau - mT <= T_3 + T_4 \\ ((m+1)(Q/D) - \tau)(P - D) - b & else \end{cases}$$

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1.3 Chapitre 2: Supply Chain Management and Multi-Agent Systems: Background

2.2 Multi-Agent Systems
The term « agent » denotes a hardware or (more usually) software based computer system, that has the following characteristics:

Autonomy: agent operates without the direct intervention of humas or others, and has some kind of control over its actions and internal state;

Social ability: agents interact with other agents (and possibly humans) via some kind of agent-communication language;

Reactivity: agents perceive their environment, (which may be the physical world, a user, a collection of other agents, the internet, or perhaps all of these combined), and respond in a timely fashion to changes that occur in it;

Pro-activeness: agents do not simply act in response to their environment. They are able to exhibit goal-directed behaviour by taking the initiative.

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1.4 Chapitre 3: The Bullwhip Effect

3.2.2 Known Causes and Some Solutions to the Bullwhip Effect

Lee et al proposed the four first causes: (1) demand forecast updating, (2) order batching, (3) price fluctuation and (4) rationing and shortage gaming. We detail these four proposed causes:

Demand forecast updating: Every company places orders based on a forecast of the future demand, and the history of incoming orders is used to forecast orders. The problem is that only retailers know the actual market consumption, and deform this information when they transmit it as orders to their suppliers. In fact, as these suppliers also want to fulfill end-customer demand, they should also base their orders on the market consumption. But these suppliers cannot do so, because they only have incoming orders to estimate end-customer demand. As a consequence, retailers make a quite accurate forecast, because they are in contact with the market, while their suppliers make worse forecasts, because they have only their incoming orders to do their forecasts.

The longer the ordering and shiping delays are, the worse this situation is, because companies have to forecast further into the future. As a consequence, ordering and shipping delays are an aggravating factor to this cause of the bullwhip effect.

Order batching: (lot sizing in a more general way) The proposed solution to lot sizing is electronic transactions (e-commerce, EDI …) to reduce transactions costs and order more frequently for smaller quantities of products.

Price fluctuation: When a company proposes a promotion, its client buy more products in order to fill their inventory. When the price is back to its usual level, the client stop buying, and consume their inventory instead. As we can see, changing the price of products also induce the bullwhip effect, because company buy more or less than their actual requirements. the proposed solution is EDLP (Every Day Low Pricing) policy, where the price is kept steady at the promotion level.

Rationing and shortage gaming: We focus here on the strategic behaviour of companies. For example, when product demand exceeds supply, some client might order more than their actual needs, because they try to have a bigger proportion of available products by « gambling », in order to receive a quantity closer to their actual needs. this amplifies order variability, because companies exagerate their real requirements during rationing, and then cancel orders when this rationing stops. As a consequence, judging the real market consumption is difficult. This behaviour occurs when the manufacturer allocates the amount in proportion to the ordered amount.
Instead of that, it is preferable as a solution to allocate the few available products in proportion to the history

of past orders.

Misperception of feedback: For example, players who do not correctly interpret their incoming orders may induce a bullwhip effect. In particular, they may smooth their orders when they should order more because the market consumption has changed.
A solution to this cause consists in giving a better understanding of the supply chain dynamics to the players.

Local optimization without global vision: local optimization means companies maximize their own profit without taking into account the effect of their decisions on the rest of the supply chain.

Variabilities due to company processes: variability in machine reliability and output, and variability in process capability and subsequent product quality. In this two causes, which are summarized as « Variabilities due to company processes ».

> L'auteur énumère les causes pouvant générer un bullwhip effect à la lumière d'une activité dont le but est de satisfaire la demande en terme de qualité et quantité. Ne sont pris en considérations que les déterminants logistiques (économiques) de la demande (coûts de possession du stock, coût de production, …) Il ne prend pas en compte les déterminants sociaux, géopolitiques, … L'auteur écarte de l'analyse un comportement irrationnel de l'entreprise (client ou fournisseur) du type criminalité économique, guerre économique, voir même semi-rationnel: coopétition avec des concurrents …
>
> Edit: A la lecture de Max Weber, il s'avère en fait que la définition de rationalité employée plus haut n'est pas exacte. En effet il ne faut pas confondre rationalité et moralité / éthique. La rationalité peut être expliquée à la lumière de la théorie des jeux, notamment en prenant en considération les équilibres de Nash: Un comportement est rationnel à partir du moment ou le joueur maximise son utilité, ce qui n'écarte pas les comportements criminels d'un équilibre même si ces comportements sont réprouvés par la morale ou les normes sociales. Pour revenir à la notion de supply chain et plus particulièrement de chaîne, il s'avère en fait que la notion tient plus de l'incantation vertueuse que d'une réalité éprouvée.
>
> L'analyse présente du bullwhip effect ne s'applique donc qu'à un marché idéal concurrentiel, ce qui réduit grandement son domaine d'application et écarte la plus grande partie de la réalité: les marchés en monopoles ou en oligopoles.
>
> En d'autres mots l'aspect guerrier de l'économie est ignoré et cela donne l'impression que l'étude est réalisée dans un monde idéal de paix. Illusion créée par les 40 ans d'enfermement dans un cocon immobiliste de la classe moyenne française liés à la guerre froide.

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1.5 Chapitre 4: Formilizing interactions with Game theory

4.1 Coordination

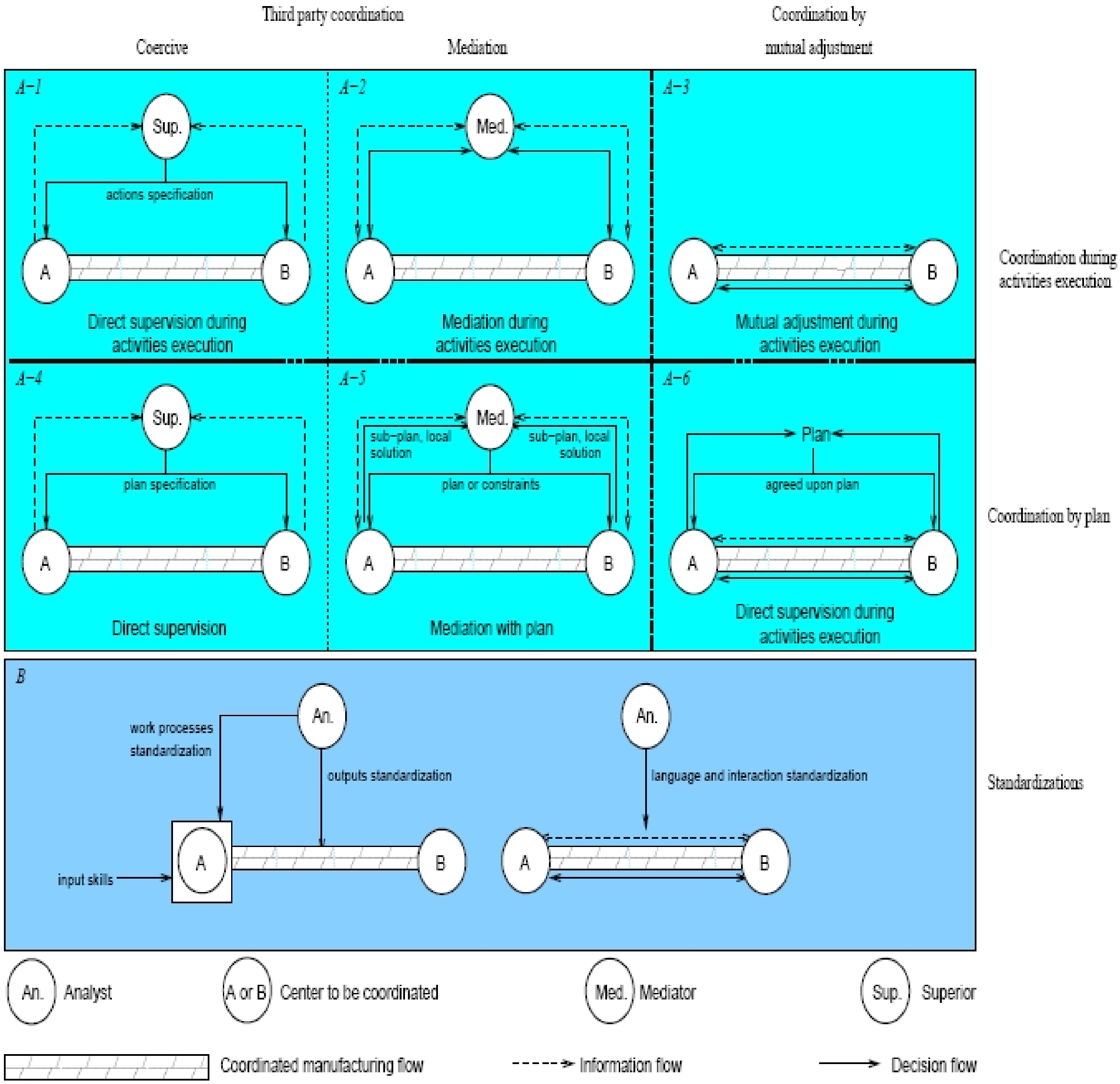

Figure 4.1: Generic classes of coordination mechanisms [Frayret, 2002].

4.1.2 Multi-agent Coordination

Communication-based coordination

Agents can coordinate by communicating together in order to find the best way, either not to disturb each other, or better, to work together. In this approach, agents negotiate to find an agreement on actions that each

agent has to perform. this negotiation may take for example, the form of an auction, such as the contract Net protocol.
Durfee and Lesser proposed the partial global Planning (PGP) as another coordination technique. since PGP interleaves coordination with action in order to coordinate in dynamic environments, this technique applies an iterative process to create, coordinate and execute plans. Moreover, decisions are taken despite incomplete and possibly obsolete information about environment. To this end, the idea of PGP is to make agents generate plans that are both partial, i.e. such plans are not for the overall system, and global, i.e. such plans are based on a non-local view of the problem. the non-local view required to build global plans is obtained by communication: each agent exchanges its local plan, and cooperates with other agents, so that to build this non-local view to have a better view of the system than the agent can perceive directly with sensors.

Convention-Based Coordination
With such coordination techniques, agents have to or should follow social laws. In general, if every agent follow the social laws, the system is supposed to be well coordinated. hence, the problem for the desinger of the multi-agent system is to find these « good » laws. some tools, such as game theory and the COOrdination Language (COOL) can help the designer in this job. According to Delgado, there exists two ways to find these laws:
Off-line design: Here social laws are given a priori to agents by the designer of the multi-agent system.
Emergent design: In this case, agents interact to decide together which laws to use in the current context. that is, agent have to agree on some common laws, but these laws are given a priori to the agents by the designer of the multi-agent system.

Learning-based Coordination
In this class, agents learn to live together, that is, they learn which action should maximize their utility depending on the current context. During this process agents learn the social laws that were applied in the class of convention-based coordination. Hence, learning is a way for the desinger to simplify his/her task, because agents find some good laws at his/her place. furthermore, it is also a way to have a more adaptive coordination mechanism, because this mechanism follows environment changes.

Commitments and Conventions as the Foundation of Coordination
The idea of this approach is that a commitment taken by an agent A provides other agents with predictability about A, so that, the other agents can predict what A could do in the future, and thus, the other agents can act according to this prediction. On the other hand, convention provide A with flexibility in face of the changes in its environment, because conventions allow A, for example, to abandon an obsolete commitment, or to pay a penalty in exchange for changing a commitment.

Coordination through Joint intentions
In some circumstances, a joint intention can be defined as a joint commitment to perform a collective action in a certain mental state. the mental state is important in this definition, because when two groups of agents share a joint commitment, one group cooperates because its members also share a certain mental state, while the other group does not cooperate. We can note that we refer here to cooperation rather than to coordination, because, as we have just stated, joint intentions assume that agents want to work together.

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1.6 Commentaire général

La fin de la thèse est intéressante. L'utilisation de la théorie des jeux dans la deuxième partie de la thèse pour étudier les comportements opportunistes des différents acteurs est un cours qui pourrait être utile pour des étudiants en logistiques. Néanmoins deux remarques surviennent:
Les variations de la fonction d'utilité matérialisée par le coût annuel ne sont pas explicitées, ce qui pourrait être nécessaire dans la mesure où il est souhaitable d'identifier le détail des postes de coûts.

Seule la conclusion aborde les aspects « extra-logistique » motivant la réticence au partage d'information. Qu'est ce qu'une Supply Chain dans la mesure ou un acteur au moins travaille pour un concurrent ?