Cooperation to Reduce Risk in a Telecom Supply Chain

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The telecom market is highly unpredictable and evolves at a very fast rate, making it extremely difficult to forecast demand accurately. These characteristics of the telecom supply chain lead to a high level of risk. One of the possible solutions for better decision making and improvement of local and global performance is the establishment of cooperative relationships within the chain. Our article presents a system and implementation methodology that aims to evaluate the risks of the actors' behaviors (resource planning strategies, production and supply control strategies, and information sharing strategies) on the performance of the individual supply chain actors and of the supply chain as a whole. This risk is evaluated according to the level of the risk attraction of the decision maker and a risk evaluation diagram is provided to the decision maker.

Introduction

Telecom supply chains are made up of all the companies that create products dedicated to telephones and telecommunications. These companies share the same mode of networking, implied actors, and mode of circulation of physical and informational flows. Generally, this chain includes four categories of actors (see figure 1):

- Global operators (GO) (e.g., France Telecom, Vodafone, Telefonica, etc.) are responsible for the deployment of network coverage and associated services provided to the customers.
- Original equipment manufacturers (OEM) (e.g., Nokia, Ericsson, Lucent) manufacture the different kinds of equipment: drivers, printers, monitors, mobile phones, and so on.
- Electronics manufacturing services providers (EMS) (e.g., Solectron, Flextronics) resell assembled products to partners who incorporate them into their own configurations and market them under their own trademark.
- The second tier supplier or semiconductor supplier (SCS) (e.g., Freescale, Philips, Texas Instrument) manufacture the basic electronic components (chips) used by the EMS.

The products involved in a telecom supply chain (telecommunication infrastructure products, mobile phones, etc.) have very short life cycles requiring a strong reactivity on the part of the various actors in order to deliver the right quantities in the right time window. If the product is not available during the right time window, several phenomena can be observed: prices fall, sales decrease, inventory becomes obsolete, and so on. Moreover, the telecom market is highly unpredictable and evolves at a very fast rate, making it extremely difficult to forecast demand accurately.

These characteristics of the telecom supply chain lead to a high level of risk. Consequently, supply chain partners are constrained to risks that grow quickly if they are not shared between actors and if the supply chain is not reactive.

One of the possible solutions for better decision making and improvement of local and global performance is therefore the establishment of cooperative relationships within the chain and more specifically the establishment of the exchange and sharing of reliable information among the different actors. Recently, many organizations have encouraged such initiatives and scientific literature provides many papers about cooperation study and analysis.

This study has been carried out in association with the manager of a semiconductor supplier who is concerned with capacity adjustment decisions in telecom supply chains. We considered capacity adjustment strategies relating to the level of the workforce and equipment for the exiting waferfabs (the acquisition of a new waferfab has not been taken into account). As the telecom supply chain is subject to rising risks, we considered it necessary that decision makers adopt a risk management approach. Several risk features have been identified relating to:

- long-range (strategic) resource planning strategies
- production and supply control strategies (pull or push)
- cooperation strategies: information (forecast) sharing strategies

In this context, we have explored a risk analysis approach based on:

- the development of a simulation tool (LogiRisk) dedicated to the testing and evaluation of different cooperative decision-making strategies
- an associated decision support methodology

In the next section we will review the relevant literature. Then we describe the simulation tool and the associated methodology. These aim to support the decision maker in identifying and evaluating individual and common risks. Then we finish with the application of the methodology and draw conclusions.

Background

In this study, we evaluate supply chain risk management, which is the "management of external risks and supply chain risks through a coordinated approach between the supply chain partners in order to reduce supply chain vulnerability as a whole" (Christopher, 2003). Up to now there has been a "lack of industrial experience and academic research for supply chain risk management" (Ziegenbein & Nienhaus, 2004) even if, since 2004, there has been an increasing number of publications in this field. Moreover, little attention has been paid to risk evaluation of new collaborative processes, especially planning processes (Småros, 2005). As discussed in our introduction, in this study we focus on two main categories of risk:

- the risks of unpredictable demand (demand risk)
- the production and control risks (pull and push strategies)

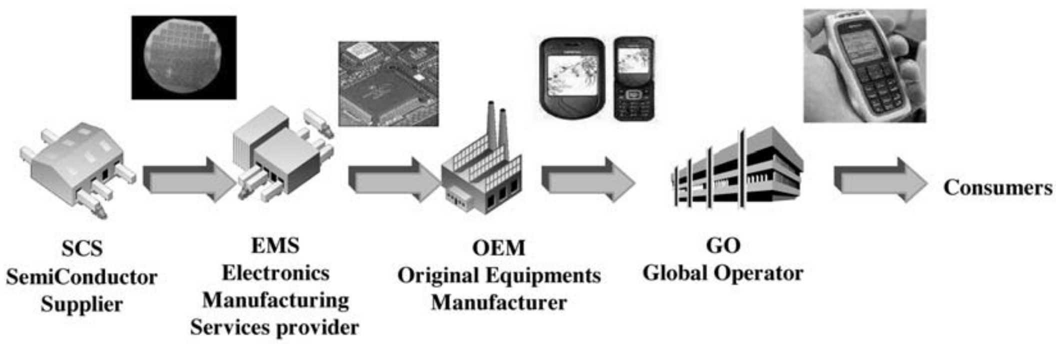
Moreover, we focus mainly on the degree of risk control that establishes cooperation among the telecom supply chain actors. Even if risk management is not explicitly involved, there is an abundance of literature related to these risk features that covers the (1) field of cooperation in the context of the supply chain (forecast exchange), (2) capacity adjustment for supply chain, and (3) push or pull strategies in the supply chain.

Cooperation in the context of SCM

Supply chain management and supply chain risk management emphasize the necessity of establishing collaborative interactions that rationalize or integrate the forecasting and management of demand, reconcile the order and book processes, and mitigate risks. Academics and practitioners are aware, in particular, of the bullwhip effect, whose influence has been clearly shown and studied (Lee, Padmanabhan, & Whang, 1997; De Souza, Song, & Liu, 2000; Hong-Minh, Disney, & Naim, 2000; Moyaux, 2004).

Recently, many organizations have encouraged trading partners to establish collaborative interactions (that rationalize or integrate their demand forecasting/management and reconcile the order-book processes) and to provide standards that could support collaboration processes: RosettaNet (Rosetta, 2008), Voluntary Inter-industry Commerce Standards Association (Vics, 2008), Odette (Odette, 2008), and so on. However, McCarthy and Golicic (2002) consider that the process of collaboration brought by the CPFR (Collaborative Planning, Forecasting and Replenishment) model is too detailed. They suggest instead that the companies should hold regular meetings to discuss

Figure 1
Telecom Supply Chain Structure



the forecast with the other supply chain partners and that they develop a shared forecast. So there is a need to evaluate these standards.

In the same way, many other research papers are devoted to the topic of cooperation in the context of supply chain management. In this article we focus on cooperation through information sharing. Using Huang, Lau, and Mak's (2003) literature review, we can distinguish different classes of information that play a role in the information sharing literature: (1) product information, (2) process information, (3) lead time, (4) cost, (5) quality information, (6) resource information, (7) order and inventory information, and (8) planning (forecast) information.

Another aspect of cooperation is extending the information sharing to collaborative forecasting and planning systems (Dudek & Stadtler, 2005; Shirodkar & Kempf, 2006). In this article, we will focus on planning information sharing (forecast), although the proposed simulation tool allows the implementation of order and inventory information sharing (Lapide, 2001; Moyaux, 2004) and collaborative forecasting and planning. Two behaviors will be studied here: a so-called not-shared forecast behaviour, when the forecast is computed by each actor based on previous demands (this behavior is used by our semiconductor supplier's partner within its telecom supply chain), and a so-called shared forecast behavior when the forecast is transmitted downstream of the supply chain demands (this behavior is used by our semiconductor supplier's partner within its automotive supply chain).

Capacity adjustment for supply chain

As supply chains have to keep up with changes in the level of consumer demand, capacity planning activities are essential. Within a given company in the supply chain, activities are "divided into three major components: long-range (strategic) resource planning, medium-range capacity planning, and production planning and scheduling. In long-range planning, a manufacturing firm plans, once every specified number of years, the number and size of its factories, including the number of production lines and workers. In medium-range planning, it plans quarterly adjustments to the number of workers and production lines. In short-term planning, it schedules production and overtime at least daily" (Budiman, 2004). The literature on capacity planning is vast. In the semiconductor field, we identified some studies relating to capacity adjustments. Bard, Srinivasan, and Tirupati (1999), for instance, studied optimized capacity expansion at semiconductor manufacturing facilities by using a nonlinear integer program to determine the number of tools at a workstation. More recently Shirodkar and Kempf (2006) proposed a uniform capacity model based on a linear integer program (which can be collaboratively used by Intel's semiconductor supply chain partners) to show that huge savings could be gained compared to a decentralized capacity model situation.

The analysis presented in this article focuses on positive/negative dynamic capacity adjustments in a decentralized model. These adjustments use a percentage of capacity variations acceptance regarding the initial capacity (this percentage is identified as a way to characterize the risk perception of the decision maker).

Push-pull strategies in the supply chain

In the 1980s and 1990s, much of the push-pull literature focused on the relative merits of push and pull systems (Spearman & Zazanis, 1992). More recently, in the context of a two-level supply chain, the preferences of the manufacturer and the retailer over the push and pull contracts have been studied. For example, Cachon (2004) studied a single-manufacturer, single-retailer supply chain with a long production lead time but fast replenishments between the actors. He showed that according to the type of wholesale price contracts (respectively push, pull, and advanced-purchase discounts), the inventory should be respectively allocated to the retailer, the supplier, or shared between them. In a supply chain with n manufacturers and a retailer Granot and Yin (2004) showed that the retailer always prefers the pull system, and manufacturers with relatively lower (or higher) manufacturing cost prefer push (or pull) to pull (or push). Gerchak and Wang's (2004) study compared push and pull modes of operation of a supply chain in an assemble-to-order environment, with an assembler sourcing components from m suppliers. They showed how the relative performance of the two modes depended on the assembly firm's share of the total cost and the number of suppliers.

This article focuses on the impact of push and pull strategies used in a medium range of time to control supply and production. This impact is related to the supply chain risks linked to the capacity adjustment decision behavior. We study both the forecast-sharing processes and the way these forecasts are used by supply chain actors (capacity adjustment and push or pull strategies) in order to define the new capacities needed to set up. We propose a simulation tool (LogiRisk) and a risk-driven methodology that takes into account the decision makers' behavior, which should help them define cooperation models for capacity planning.

A simulation tool for collaborative S&OP processes: LogiRisk

The simulation tool

Logirisk is a simulation tool that focuses on the sales and operation planning (S&OP) processes relating to capacity adjustment. During these processes the top

Figure 2
Time Advance and the Simulation of Processes

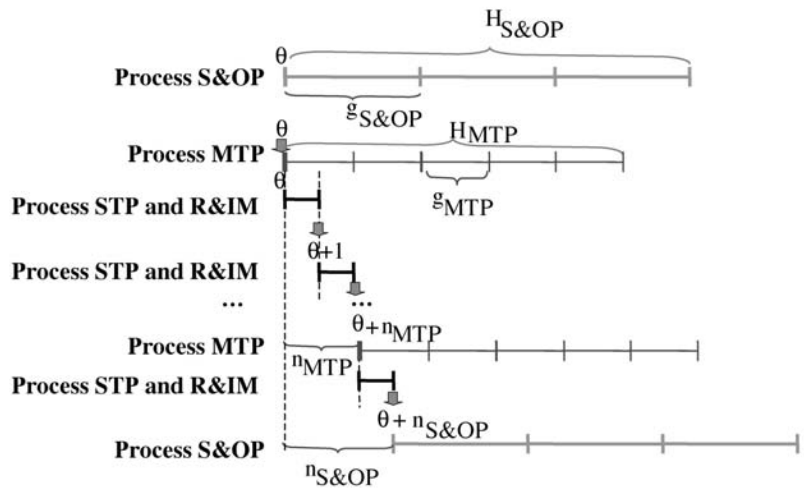
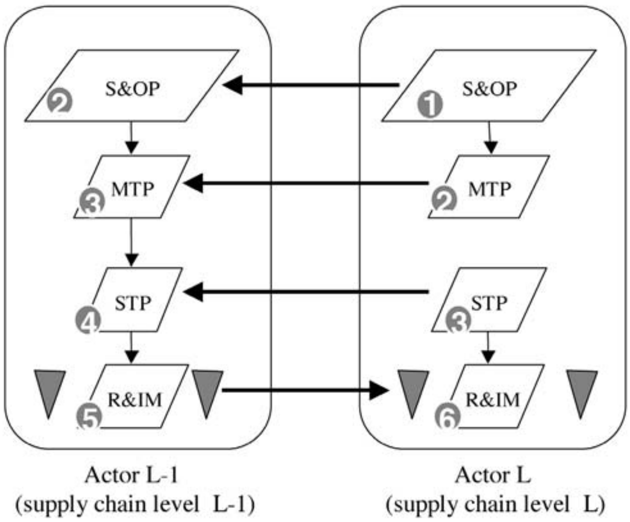


Figure 3
Upstream Planning Coordination Mechanism



management of each actor can adjust the capacity variation proposed by the aggregate production planning and apply a subjective ratio (depending on its willingness to take risk). Furthermore, medium-term planning (MTP), short-term planning (STP), and release and inventory management (R&IM) are considered to evaluate the influence of push and pull strategies and of short-term planning loops on the efficiency of the S&OP process.

Logirisk is a time-bucket driven discrete event simulator. It simulates the rolling horizon integration of planning processes (see figure 2). Time is divided in elementary time buckets. Each planning process produces plans that are characterized by a horizon (H), a granularity of time (g), and a number of time buckets of validity before replanning (n). At each starting date θ of a time bucket, the planning processes are simulated according to a coordination mechanism. Once all the planning processes of an actor have been simulated, the R&IM process also gives the resulting state of this actor at the end of the time bucket. Once all the actors have run their R&IM processes, the simulation can jump to the next time bucket: $\theta+1$.

Our objective is then to model the dynamics of the planning processes of the various actors in a supply chain. The coordination mechanism and the model of the actors' processes (planning processes focusing on the decision maker's behaviors) are presented below.

An upstream coordination mechanism

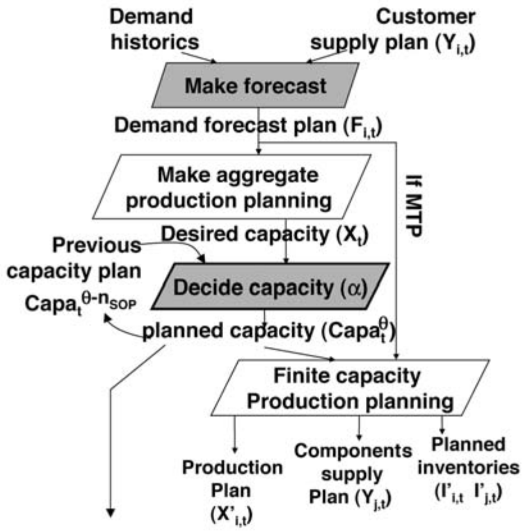
In this article an “upstream planning” (Dudek & Stadtler, 2005) coordination mechanism is considered (figure 3 illustrates this coordination scheme for two actors). It consists of activating planning processes level by level (at the supply chain level) and hierarchically (at the actor level) taking into account their replanning periods (rolling horizon process). This coordination mechanism gives precedent relationships between processes (the arcs in figure 3) so that an order can be obtained for the simulation of the various processes (the numbers in figure 3).

In the following, some simulations are made assuming that no coordination mechanism exists between actors. In these cases, planning processes are made according to the actors' own forecasts (instead of plans transmitted by customers) but the order of simulation of the processes does not need to be changed.

Decision makers' behaviors during a planning process

When describing a planning process, some of the activities (in white in figures 4, 5, and 6) refer to classical operation management calculation, and others (in grey) model the way a manager interprets conflicting results of these calculations and finally makes choices. We are particularly interested in this second type of activity in the sense that they define the behavioral choices of decision makers and can influence the whole supply chain throughout the coordination mechanism.

Figure 4
S&OP and Medium Term Planning Processes



In the following, the planning processes of an actor are detailed at the starting date Θ of a time bucket. The variables of the models are introduced. We explain the context and the principle of the decision makers' behaviors. A complete algorithmic description of the processes can be found in the appendix.

Sales and Operation Planning (S&OP) (Figure 4): Periodically (every $n_{S\&OP}$ time bucket), the actor defines the sales forecast $F_{i,t}$ of its finished products *i* along a planning horizon (tE1;$H_{S\&OP}$]). This forecast is made either locally (using an endogenous forecasting model applied to demand histories, Holt-Winters in this application) or using procurement plans, $Y_{i,t}$, transmitted by the customers.
Here managers can apply some distortion (anticipation, amplification) to this forecast. With this forecast, an aggregate production plan X_t is realized that integrates a load-smoothing strategy. It is considered by the top management as an ideal capacity plan in order to meet the forecast $F_{i,t}$. But, because of forecast changes between two successive S&OP processes, it is also slightly different from the capacity plan, $Capa_t^{\theta\text{-nSOP}}$, that was validated at the previous S&OP process. When drastic differences appear, management makes a decision based on its confidence in the forecast $F_{i,t}$. Here, the more or less risky behavior of the top management is modelled with parameter α: only a percentage α of capacity variation between X_t and $Capa_t^{\theta\text{-nSOP}}$ is accepted.

Under this capacity constraint, $Capa_t^{\theta}$, the finished products' production $X'_{i,t}$, output inventory I'i,t, and the raw material supply Yj,t and input inventory $I'_{j,t}$ of component *j* are planned.

Medium-Term Planning (MTP): The MTP process is more frequently launched than S&OP ($n_{MTP} < n_{S\&OP}$), with a shorter granularity ($g_{MTP} < g_{S\&OP}$), and is constrained by the capacity decided in the previously occurring S&OP. In our model, it is equivalent to an S&OP process without capacity decision: forecasts and finite capacity planning are updated and expressed in the MTP granularity.

Short-Term Planning (STP): This process (see figure 5) models what an actor tries to do during a time bucket given its production and supply strategies (push or pull). In our model, push strategy gives priority to production ($X'_{i,t}$) and supply ($Y_{i,t}$) planned during the MTP. Conversely, the pull strategy aims at reconstituting the planned inventories ($I'_{i,t}$ *and* $I'_{j,t}$) given the consumption of the inventories (customer demand of finished products and use in production of raw materials). Consequently, for each finished product *i*, the admissible production release XPi is computed according to the production push or pull strategy and the effective availability of the capacity (breakdowns are integrated here ; capacity is shared among the products proportionally to their desired demand). Meanwhile, a procurement order D_j is placed with the supplier according to the supply strategy (push or pull).

Release and Inventory Management (R&IM): This process (figure 6) models what an actor actually does during a time bucket given the effective availability of components. First, the actor notes component receipts (DL_j) that can be different from the order (D_j) placed one delivering cycle time before. The actor deduces new planned receipts for components ($RP_{j,\theta+1}$ backorders are due on the next time bucket in our model), and the usable component quantity. Then, the actor decides the effective production release $\overline{X_i}$ according to this availability of components and the production priorities. Meanwhile, finished products are received from production and delivered according to the customer's demand. Here as well, backorders can appear. In such cases, managers must decide how many products to deliver (DL_i) to each customer: in our model backorders are shared between the customers proportionally to their demand (D_i).

With this description of planning processes, it can be noted that the behavior of the decision makers are introduced through the:

- use (or not) of supply plans from customers in order to make the forecasts
- parameter α that models the ability of managers to admit changes of capacity planning for a given period of time between two successive S&OP processes
- choice of a push or pull strategy for managing production and supply

Figure 5
Pull and Push Strategies in the Short-Term Planning Process

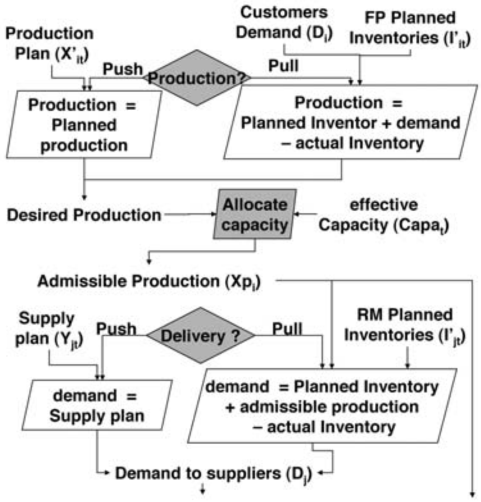
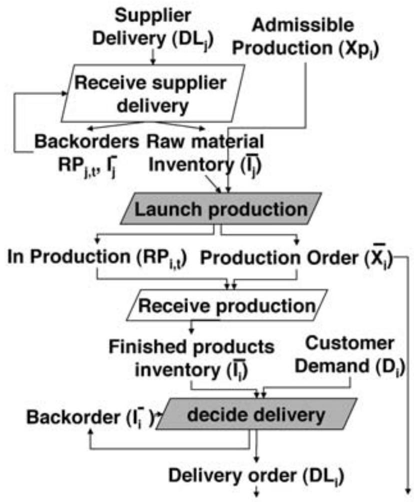


Figure 6
Release and Inventory Management Process



- way backorders are shared between item references when capacity limit is reached in STP and R&IM processes or between customers when finished products don't meet demand.

Implementation methodology for evaluation of cooperative processes

As one of our main goals is to create reliable partnerships, it is necessary to establish a discussion between the decision makers of the different entities. We propose an implementation methodology that can be outlined in six steps (see figure 7):

1. Problem selection: Presentation of the actors concerned and expression of the context in which the decision takes place. Definition of the fundamentals of the specific cooperative strategies that are to be evaluated. This step consists of a viewpoint confrontation process and is led by an external organizer (e.g., the tool designer) (Thierry, Lauras, Lamothe, Mahmoudi, & Charrel, 2006).
2. Design of experiment: The combination of parameter values to be simulated are defined.
3. Parameter instantiation in LogiRisk.
4. Simulation: Simulations are performed over a time horizon of several years and indicators are computed

Figure 7
The Implementation Methodology

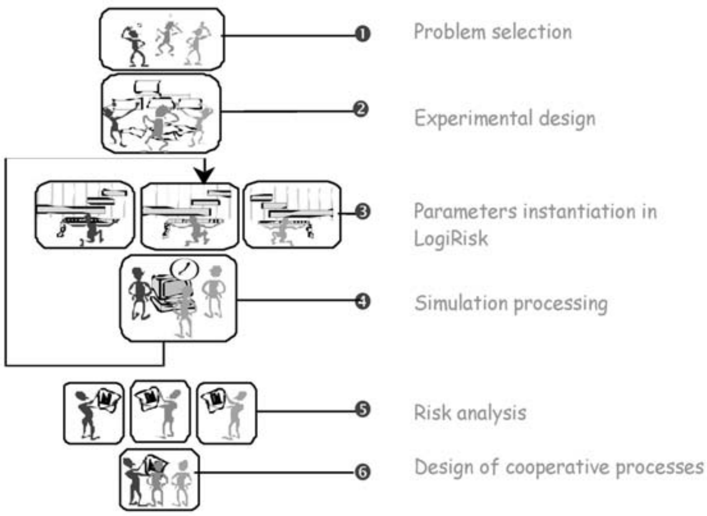
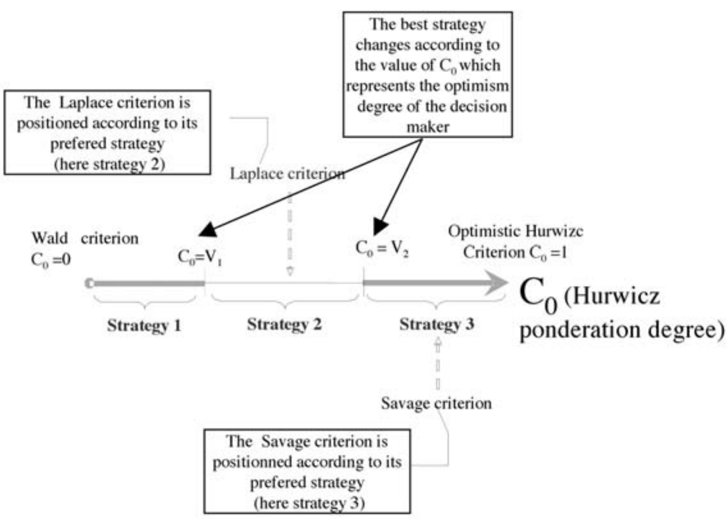


Figure 8
Risk Diagram



5. Risk analysis: In this step, the risks of the different cooperation strategies are expressed either for the whole supply chain or for each actor in the chain. Various criteria can be used to evaluate the strategies: Laplace criterion (mean), Wald criterion (pessimistic), Hurwicz criterion (optimism ponderation), Savage criterion (minimize the maximal regret), and so on. The evaluations obtained with these criteria can be synthesized in a risk diagram to support the decision maker. In this diagram, the different strategies are positioned according to the optimism ponderation degree of the Hurwicz criterion. Moreover, the preferred strategies are positioned on the diagram (figure 8) according to the Laplace and Savage criteria.
6. Design of cooperative processes: This leads to the conclusion of the partnership contract relating to the choice of cooperative processes.

Implementation of the methodology in a case study

Problem selection

Our objective is to measure, in a global but also local perspective, the risks connected to the following strategies:

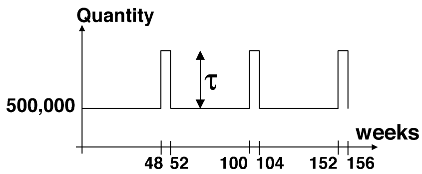
- capacity management (α SCS percentage of acceptance of the proposed capacity variation)
- requirement forecast exchange (or not) (two strategies are considered: “shared forecast” and “not shared forecast”)
- production and supply strategies (push or pull strategies set up by the OEM and the EMS)

This evaluation will be performed in terms of risks, according to different market development scenarios. Figure 2 shows the supply chain under study. The production and delivery cycle times are chosen in conformity with the telecom sector: short for the OEM and the EMS, long for the SCS.

Design of experiment

The chosen strategies will be evaluated according to various scenarios of demands. The average demand is 500,000 products per week during the first 11 months of the year. We consider that there is a peak in the market demand in December (see figure 9). This peak is expressed via a percentage of increase τ with regard to the forecast of the other months. could be weak, 10 %; average, 50 %; or important, 100 %

Figure 9
Market Forecasts Profile



We also take into account the reliability of the demand with regard to the forecast. This demand is calculated using a normal law without bias *Demand (t) = N (Forecast (t), σ)*, where σ ∈ {0; 10000; 50000; 100000; 250000}.

Parameters instantiation in LogiRisk

The decision makers now enter their parameters and strategies, which have already been worked out by the previous experimentations. Here each decision maker is going to be able to test the following:

- different strategies of capacity management for the SCS: a percentage of acceptance of the proposed capacity variation: α_{SCS}=50 %, α_{SCS}=75 %, α_{SCS}=100 %
- different strategies of information sharing: shared/not shared forecast
- different production and requirement strategies set up by the OEM and the EMS: push/pull strategies.

Simulation processing

The simulations run over a time horizon of 12 years. Each simulation returns for each time bucket θ of the horizon: the effective capacity of each actor A, $Capa^A\theta$; the effective production release of each product i, $\overline{X_i}$; the finished product, $\overline{I_i}$, and component inventory, $\overline{I_j}$, of each actor; and the stock-out of finished products of each actor, I_j.
The SCS manager associated with the present study fixed elementary costs. Then cost indicators were calculated for each strategy and each scenario during a four-year period (between week 208 and week 416) from both local (i.e., for each actor of the supply chain) and global (i.e., for the supply chain as a whole) perspectives:

- release costs: the costs of production release:

$$Cp_A = \sum_{i \in I_A, \theta \in \Theta} cp_i \times \overline{X}^A_{i,\theta}$$

- capacity acquisition costs: the costs associated with the acquisition of new capacities:

$$Ca_A = \sum_{\theta \in \Theta} ca_A \times \left| Capa^A_\theta - Capa^A_{\theta-1} \right|$$

- stock holding costs: the costs of keeping stocks: ,

$$Cs_A = \sum_{i \in I_A, \theta \in \Theta} cs_{i,A} \times \overline{I}^A_{i,\theta} + \sum_{j \in I_j, \theta} cs_{j,A} \times \overline{I}^A_{j,\theta} \quad / \quad \overline{I}^A_{i,\theta} \geq 0, \overline{I}^A_{j,\theta} \geq 0,$$

- and stock-out costs: the costs of the stock-outs that occur when the supply chain has no finished products to satisfy the market demand:

$$Cso_A = \sum_{i \in I_A, \theta \in \Theta} cso_{i,A} \times (I^-_{j,\theta}) \quad / \quad \overline{I}^A_{i,\theta} < 0$$

where Θ is the performance assessment horizon.
This allows us to go to the next step: risk analysis.

Risk analysis

First, we analyze the present OEM and EMS strategies (pull strategy and not shared forecast). Then we will study the push strategy and shared forecast and pull strategy and shared forecast. Within these studies, we distinguish two situations:

- decision under risk: probabilities characterize the market scenario occurrence

Figure 10
SCS Cost (OEM+EMS Present Strategy)

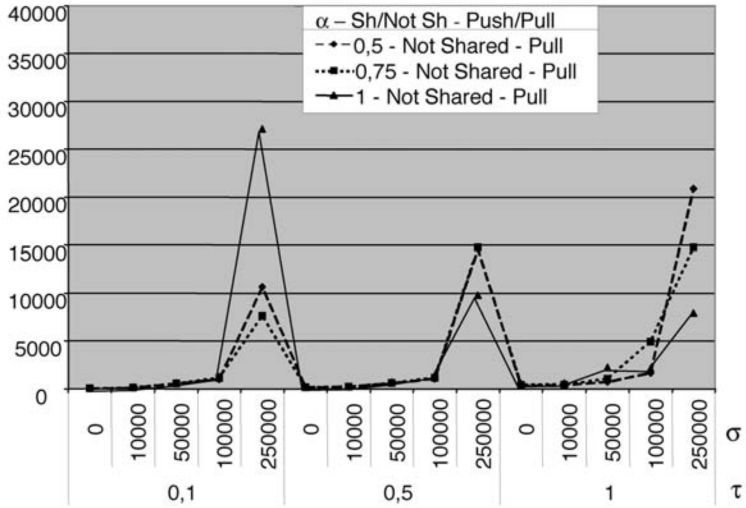
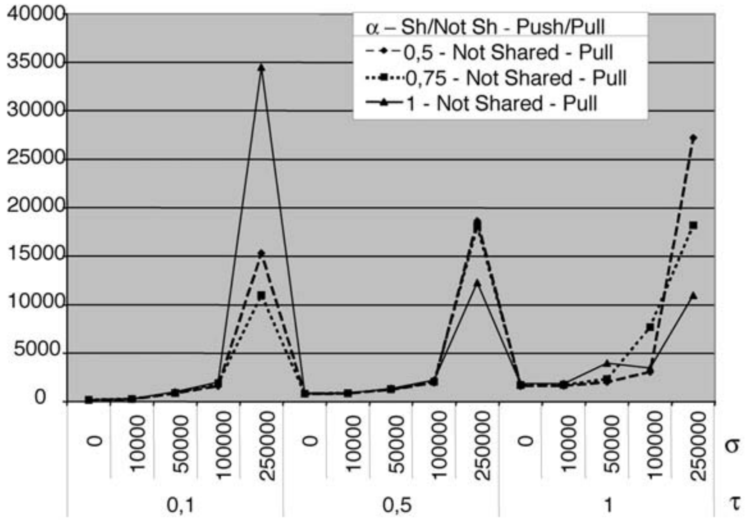


Figure 11
Total Cost (OEM+EMS Present Strategy)



- decision under uncertainty: probabilities to characterize the market scenario occurrence are not available

For each situation, we distinguish two perspectives: the first one focuses on local interest of the semiconductor supplier; the second one focuses on the global interest of the supply chain.

OEM+EMS present strategy: pull/not shared forecast

Let us first consider the present OEM and EMS strategies (pull strategy and not shared forecast) to evaluate the influence of α_{SCS} on the SCS costs and on the whole supply chain costs. The results relating to the evaluation of the influence of the α_{SCS} according to various scenarios of demands (characterized by τ, σ) are presented in figure 10 (SCS cost) and figure 11 (global cost). Nevertheless, it is very difficult to conclude without taking into account the probabilities of occurrence of the different scenarios or the level of risk attraction of the decision maker (if these probabilities are not available).

- **Decision under risk**

In this part we consider that the decision makers can define the probability of occurrence of the predefined scenarios (see Table 1):

Table 1
Probability Indexes of the Different Scenarios (5 = high)

τ \ σ	0	10000	50000	100000	250000
10%	1	2	3	4	3
50%	2	3	4	5	4
100%	1	2	3	4	3

Using this probability distribution, the computation of the expected costs for the different strategies allows us to obtain table 2:

Table 2
Expected Cost Evaluation

α_{SCS}	Pull Not Shared Local Cost	Pull Not Shared Global Cost
50 %	4029	5763
75 %	**3787**	**5299**
100 %	4073	5663

Using this criterion the decision to take is α_{SCS} = 0,75. This decision is the most interesting for the SCS as well as for the supply chain as a whole.

• Decision under uncertainty

Nevertheless, the frequency probability of the retained scenarios is not always available, so the evaluation of a given strategy cannot be computed using expected value criteria. Thus we compute several decision theory criteria to help chose the best global strategy when we study all the costs resulting from the different scenarios. The following criteria were used:

- *The pessimistic (Wald or minimax) criterion:*

$$\underset{p \in policies}{Min}\left(\underset{s \in scenarios}{Max}\left[\cos ts(p,s)\right]\right)$$

- *The Hurwicz optimistic criterion:*

$$\underset{p \in policies}{Min}\left(\underset{s \in scenarios}{Max}\left[\cos ts(p,s)\right]\right)$$

- *Hurwicz weighted criterion:*

$$\underset{p \in policies}{Min}\left(C_0 . \underset{s \in scenarios}{Min}\left[\cos t(p,s)\right] + (1 - C_0) . \underset{s \in scenarios}{Max}\left[\cos ts(p,s)\right]\right)$$

It is a weighted mean between the optimistic and pessimistic criteria. The weight C_0 expresses the aversion of the decision maker to the uncertainty.

- *Laplace criterion:*

$$\underset{p \in policies}{Min}\left(\sum_{s \in scenarios} \cos ts(p,s) / n_{scenarios}\right)$$

This criterion postulates that if no frequency probability is available for the various scenarios, it means they are all equally likely.

- *Savage minimax regret criterion:*

$$\underset{p \in policies}{Min}\left(\underset{s \in scenarios}{Max}\left[\cos ts(p,s) - \underset{q \in policies}{Min}\left\{\cos ts(q,s)\right\}\right]\right)$$

This criterion selects the strategy that minimizes the maximum regret (i.e., when a particular scenario occurs, regret is the cost of a selected strategy compared to the cost of the best strategy, for this the particular scenario).

The following results (see table 3) can be obtained for the present OEM+EMS strategy (pull and not shared forecast): To synthesize these criteria, a risk diagram (see figure 12) is proposed relating to the level of risk attraction. As local and global costs lead to the same decision, only SCS costs are considered.

According to the level of risk attraction the decision maker will choose α_{SCC} = 75% (low or medium attraction level) or α_{SCS} = 50% (high attraction level: the best cases are considered).

Table 3
The SCS Strategies (α_{SCS}) Evaluation Using the Different Criteria

SCS Capacity Strategies	Wald		Hurwizc		Laplace		Savage	
α_{SCS}	Local	Global	Local	Global	Local	Global	Local	Global
50 %	20876	27211	**25**	**154**	3523	5140	19964	23762
75 %	**14772**	**18190**	46	176	**3209**	**4593**	**13883**	**15249**
100 %	27118	34491	50	181	3659	5169	26242	31922

SCS Capacity Strategies	Hurwicz 0.1		Hurwicz 0.2		Hurwicz 0.3		Hurwicz 0.4	
α_{SCS}	SCS	Global	Local	Global	Local	Global	Local	Global
50 %	18790	24505	16705	21799,6	14620	19093	12535	16388
75 %	**13299**	**16388**	**11826**	**14587**	**10354**	**12785**	**8881**	**10984**
100 %	24411	31060	21704	27629	18997	24198	16290	20767

Hurwicz 0.5		Hurwicz 0,6		Hurwicz 0,7		Hurwicz 0,8		Hurwicz 0,9	
Local	Global	Local	Global	Local	Global	Local	Global	Local	Global
10450	13682	8365	10976	6280	8271	4195	5565	2110	2859
7409	**9183**	**5936**	**7381**	**4463**	**5580**	**2991**	**3778**	**1518**	**1977**
13584	17336	10877	13905	8170	10474	5463	7043	2756	3612

OEM+EMS other strategies

The necessity of establishing collaborative interactions (sharing forecasts) has been identified. Thus we will now evaluate the potential benefit of forecast sharing. In addition, pull and push strategies will be considered. First, these strategies can be compared to the present strategy (see figure 13 and figure 14). Whatever the strategy (pull or push), the transmission of forecast improves the results in terms of SCS (figure 13) and global costs (figure 14): the dotted lines are always higher than the full lines.

Then it can be noticed in these cases (forecast sharing) that the results can be considered not α dependant (see figure 15 and figure 16).
Nevertheless according to the point of view (local or global cost), the preferred strategy is not the same (see figure 17 and figure 18).
The different criteria can be computed (see table 4).

Let us consider independently the global and local perspectives. From the SCS perspective, the shared forecast-pull strategy should be always chosen. From the whole supply chain perspective, the shared forecast-push strategy should be preferred.

Design of cooperative processes

The choice of the strategy should be decided jointly. As OEM+EMS are concerned with the choice of the push or pull strategy, the shared pull strategy will be adopted. As a matter of fact, the SCS has no argument to convince the other actors to change for the best strategy (shared push).

Figure 12
Risk Diagram for the pull-Not shared forecast strategy

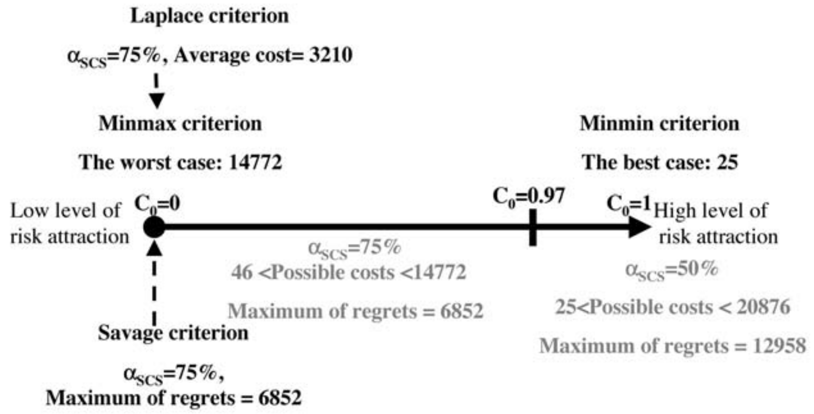
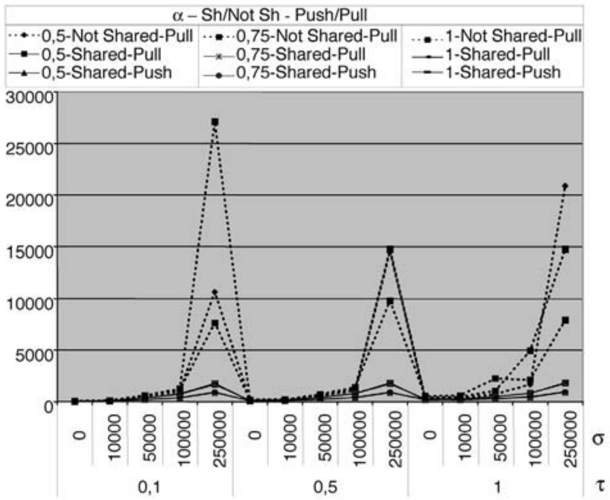


Figure 13
SCS Cost Comparison
(Pull/Not Shared, Push and Pull/Shared Forecast Strategies)



Conclusion

A simulation methodology has been presented to improve cooperation strategies within a telecom supply chain. We propose to evaluate the risks from global and local perspectives of various cooperative strategies: production/ requirement strategies coupled with different behaviors of the actors at the capacity adjustment level.

A three-stage telecom supply chain facing a fluctuating market was studied. We have shown that the local and global interests are to set up a shared forecasting system. We stressed that the results are not dependent of the SCS acceptance of capacity variation. Moreover, the global perspective leads to a pull shared forecast strategy, even if from the point of view of the SCS, a push shared forecast strategy should be preferred.

Future research should focus on a multiproduct supply chain. New market behaviors should be investigated: forecasts/demand adjustment scenarios, market change of tendency scenarios, and delays/advances on the launching of a product on the market. Moreover, the influence of order and inventory information sharing and collaborative forecasting and planning have to be studied in this context because they have been identified as interesting risk mitigation features.

Figure 14
Global Cost Comparison (Pull/Not Shared, Push and Pull/Shared Forecast Strategies)

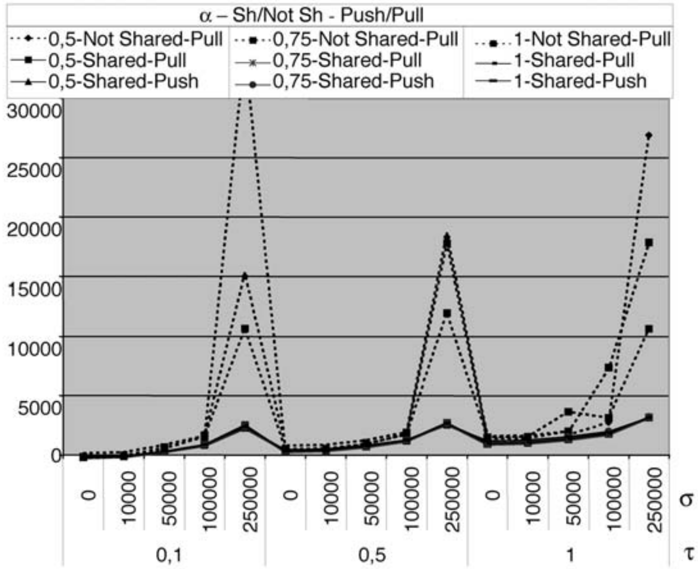


Figure 15
α_{SCS} Dependence of Costs (Pull/Shared Forecast Strategy)

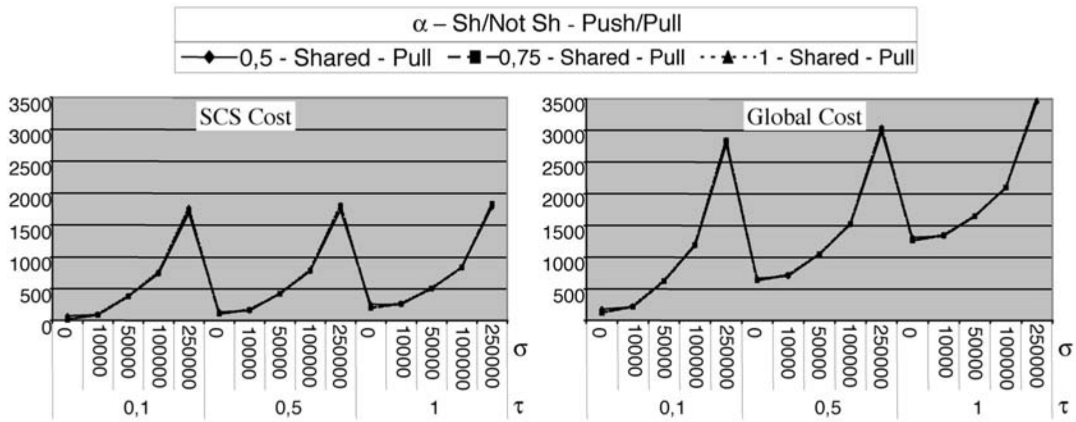


Figure 16
α_{SCS} Dependence of Costs (Push/Shared Forecast Strategy)

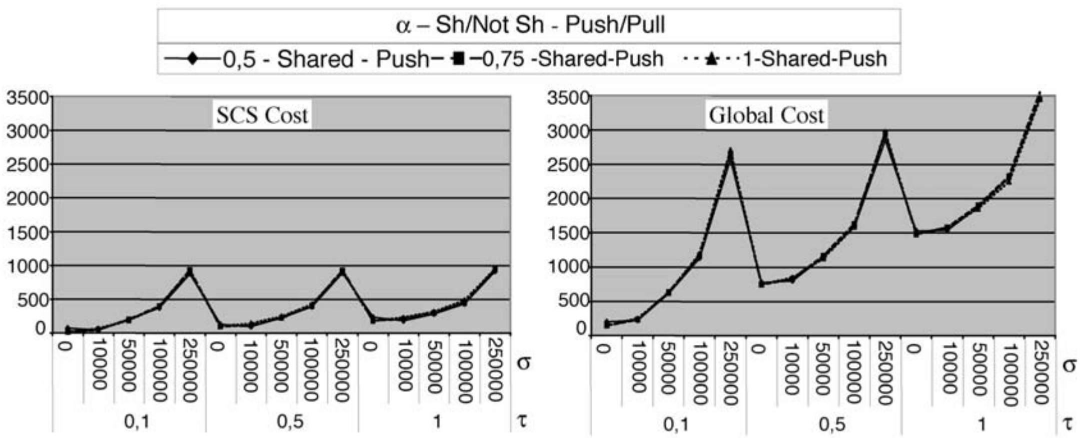


Figure 17
Local Cost Comparison (Push and Pull/Shared Forecast Strategies)

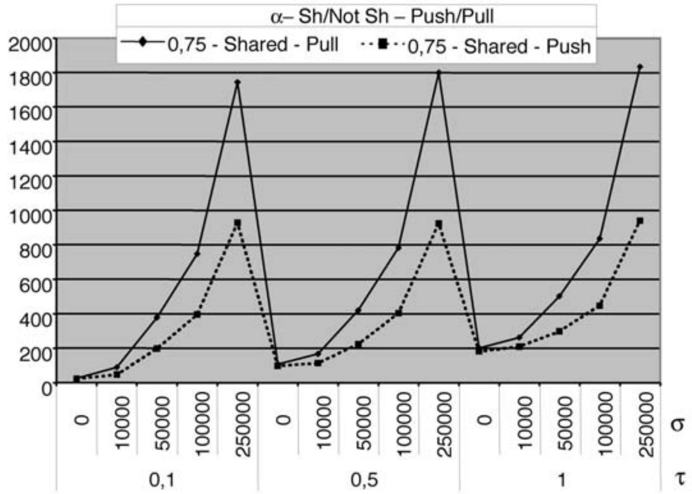


Figure 18
Global Cost Comparison (Push and Pull/Shared Forecast Strategies)

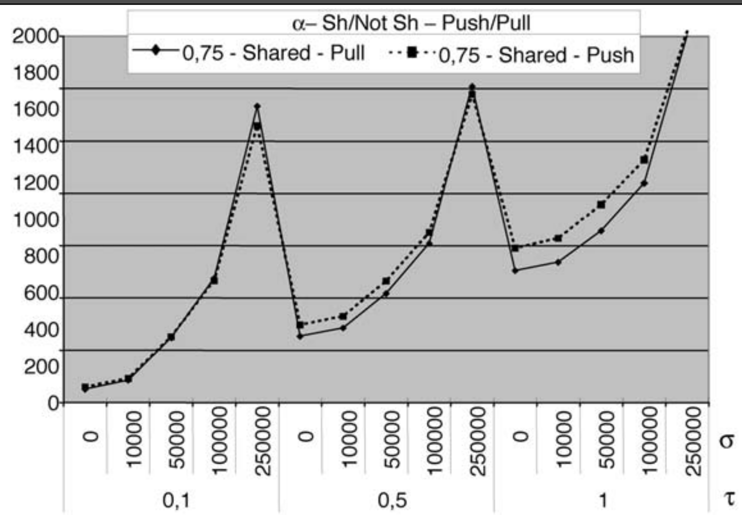


Table 4
The SCS Strategies (α_{SCS}) Evaluation Using the Different Criteria

The SCS Capacity Strategies	**Wald**		**Hurwizc**		**Laplace**		**Savage**	
Strategies	Local	Global	Local	Global	Local	Global	Local	Global
Push	**940**	3552	**22**	152	**362**	1531	**0**	251
Pull	1833	**3507**	24	**130**	659	**1431**	893	**185**

The SCS capacity strategies	Hurwicz 0,1		Hurwicz 0,2		Hurwicz 0,3		Hurwicz 0,4		Hurwicz 0,5	
Strategies	SCS	Global	Local	Global	Local	Global	Local	Global	Local	Global
Push	**848**	3212	**756**	2872	**665**	2532	**573**	2192	**481**	1852
Pull	1652	**3169**	1471	**2832**	1290	**2494**	1109	**2156**	929	**1819**

The SCS Capacity Strategies	Hurwicz 0,6		Hurwicz 0,7		Hurwicz 0,8		Hurwicz 0,9	
Strategies	Local	Global	Local	Global	Local	Global	Local	Global
Push	**389**	1512	**294**	1172	**206**	832	**114**	492
Pull	748	**1481**	567	**1143**	386	**805**	205	**468**

Appendix

This appendix details the procedures that were implemented to model the S&OP, MTP, STP, and R&IM processes in the case study. These procedures translate what a generic actor A does at a given date θ, when a process is launched.

First we introduce the hypothesis. Then the notations and the procedures are presented. It must be noted that these procedures do not incorporate any mathematical programming optimization.

Hypothesis

The supply chain is linear: each actor has exactly one supplier and one customer.

Each actor manages a single resource, the bottleneck. Production lot sizes are equal to 1.

Products are considered as families as seen from the S&OP process point of view. Each actor produces a single item from a single component.

The SCS uses push strategy (long lead times); the OEM and the EMS can use pull or push strategies (shorter lead times).

We do not consider any distortion of information in the manager's behaviors before using or transmitting it.

For a given process, all the actors use the same horizon, granularity, and replanning period.

When disaggregating plans, we pose the equity principle: quantities are equitably distributed over the time buckets of each planning period.

The whole system is supposed to be reliable; there is no random phenomenon.

Notations

Customer, supplier: the customer and the supplier of the actor

p: processes ($p \in$ {S&OP, MTP})

(respectively j): final item (respectively. component) of the actor

t period number in a plan

θ time at which a process is launched and variables are computed

[]: round up operator

Data

T_p: number of periods of the planning horizon for the process $p \in$ {S&OP,MTP}

g_p: granularity, number of time buckets in a period of a plan of the process $p \in$ {S&OP;MTP;STP}

n_p : the process $p \in$ {S&OP,MTP} is relaunched every n_p time buckets

l_i (respectively. l_j): production (respectively. supply) lead time of item i (respectively of component j)

α: acceptance of capacity variation (%)

Variables

D_i: demand, firm orders of item i received for actor A at time θ from customer c

$F_{i,t}^{p}$: forecast of item i at period t for the process $p \in$ {SOP;MTP}

$RP_{i,\theta}$: planned receipts of item i at time bucket θ

$\bar{I}_i$ (respectively $\bar{I}_j$): actual inventory position of item i (component j)

X_t: desired capacity for period t in the S&OP process

$Capa_{t}^{\theta}$: planned capacity decided at time bucket θ for period t in a S&OP process

$X^{p}_{i,t}$ (respectively $X'^{p}_{i,t}$): planned production for period t at infinite (respectively finite) capacity for item i in process p

$Y^{p}_{j,t}$: supply requirement planned for period t and item j in the process p

$I^{p}_{i,t}$ (respectively $I'^{p}_{i,t}$): planned inventory of item i or j at infinite (respectively finite) capacity at the end of period t in process p

XP_{i} (respectively $\overline{X}_{i}$): admissible (respectively effective) production release of item i

I^{-}_{i} : inventory shortage of item i

$DL_{i,\theta}$: delivery of item i to the customer decided at time bucket θ

<u>Basic functions</u>

$RP^{p}_{i}(t)$: returns the planned receipts of item i for period t in the planning process p

$$RP^{p}_{i}(t) = \sum_{u=0}^{g_p - 1} RP_{i,\theta + (t-1).g_p + u}$$

$Capa^{p}(t)$: disaggregates the last decided capacity plan (at time bucket θ') and gives the available capacity for period t of the process $p \in \{S\&OP;MTP;STP\}$,

$$Capa^{\theta}(t) = \frac{1}{g_{S\&OP}} Capa^{\theta'}_{\lceil(\theta + t.g_p - \theta')/g_{S\&OP}\rceil}$$

<u>S&OP or MTP Processes</u>

SOP_MTP_process (p) { // p∈{S&OP,MTP}

//sales forecast computation

IF (exist collaboration) { For t∈[1, T_p], $F^{p}_{i,t} \leftarrow Y^{p}_{i,t}$ }

else {For t∈[1, T_p], $F^{p}_{i,t} \leftarrow \text{Holt-Winters}\left(histories\ of\ D_i, \{0.3;0.3;0.1\}\right)$ }

// Aggregate planning

$I^{p}_{i,0} \leftarrow \bar{I}_{i}$

For t∈[1, l_i], $I^{p}_{i,t} \leftarrow I^{p}_{i,t-1} - F^{p}_{i,t} + RP^{p}_{i}(t)$

For t∈[l_i+1,T], $I^{p}_{i,t} \leftarrow 0$ and $X^{p}_{i,t-l_i} \leftarrow F^{p}_{i,t} - RP^{p}_{i}(t) - I_{i,t-1}$

IF (p = S&OP) {

// load smoothing and desired capacity deduction

$\{X_t / t \in [1, T_{S\&OP}]\} \leftarrow$ Load_smoothing ($\{X_{i,t} / t \in [1, T_{S\&OP}]\}$, l_i)

// Capacity decision

For t ∈[1, $T_{S\&OP}$], $Capa^{\theta}_{t} \leftarrow (1-\alpha).Capa^{\theta - n_{S\&OP}}_{t} + \alpha.X_t$

}

//Production planning with finite capacity

$I'^{p}_{i,0} \leftarrow \bar{I}_{i}$ and $I'^{p}_{j,0} \leftarrow \bar{I}_{j}$

$\{ X'^{p}_{i,t} \,/\, t \in [1, T_p]\} \leftarrow$ Load_smoothing_with_capacity $(\{ X^{p}_{i,t} , Capa^{p}(t) / t \in [1, T_p]\})$

For $t \in [1, T_p]$, $I'^{p}_{i,t} \leftarrow I'^{p}_{i,t-1} + X'^{p}_{i,t} - F^{p}_{i,t} + RP^{p}_{i}(t)$

// Supply planning

For $t \in [1, l_j]$, $I^{p}_{j,t} \leftarrow I^{p}_{j,t-1} - X'^{p}_{i,t} + RP^{p}_{j}(t)$

For $t \in [l_j+1, T]$, $I^{p}_{j,t} \leftarrow 0$ and $Y^{p}_{j,t-l_j} \leftarrow X'^{p}_{i,t} - RP^{p}_{j}(t) - I'^{p}_{j,t-1}$

}

The Holt-Winters() function refers to the Holt-Winters endogenous method for forecast generation with tendency and seasonality.

The Load_smoothing() function does not take into account any capacity plan, and therefore generates an ideal smoothed load plan. In the case study, it simply is a moving average over the production lead time.

Load_smoothing($\{ X^{p}_{i,t} / t \in [1, T_p]\}$, l_i) {

For $t \in [1, T_p]$, $X_{t} \leftarrow \sum_{u=0}^{l_i-1} X^{p}_{i,t+u}$

}

The Load_smoothing_with_capacity() function aims at smoothing a production plan into a given capacity plan. In the case study, the production is placed as late as possible if there can be no late production times and as soon as possible otherwise.

Load_smoothing_with_capacity $(\{ X^{p}_{i,t}, Capa^{p}(t) / t \in [1, T_p]\})$ {

Let Smooth =0 //Smooth is the production that must be anticipated

For $t \in [T_p, 1]$ {

Let $X^{1}_{i,t} \leftarrow Min(Capa^{P}(t); X^{P}_{i,t} + Smooth)$

$Smooth \leftarrow X^{P}_{i,t} - X^{1}_{i,t} + Smooth$

}

//Smooth is the production that cannot be anticipated. It is placed as soon as possible.

For $t \in [1, T_p]$ {

Let $X^{2}_{i,t} \leftarrow Min(Capa^{P}(t) - X^{1}_{i,t}; Smooth)$

$Smooth \leftarrow Smooth - X^{2}_{i,t}$

$X'_{i,t} \leftarrow X^{1}_{i,t} + X^{2}_{i,t}$

}

}

STP process

The STP process function is launched for every time bucket. MTP planned productions and inventory variations during the first MTP period are disaggregated supposing the equity principle.

STP_process () {

// computing the admissible production

If (Push production), $XP_i \leftarrow X'^{MTP}_{i,1} \big/ g_{MTP}$

Else $XP_i \leftarrow \min\left(D_i + (I'^{MTP}_{i,1} - \bar{I}_i)/g_{MTP}; Capa^{STP}(1) \right)$.

// computing the procurement order

IF (Push procurement), $D_j \leftarrow Y^{MTP}_{j,1} / g_{MTP}$

Else $D_j \leftarrow \alpha_{i,j} XP_i + (I'^{MTP}_{j,1} - \bar{I}_j)/g_{MTP}$

$RP_{j,\theta + l_j} \leftarrow D_j$ //procurement orders are awaited at the end of the procurement lead time.

}

R&IM Process

The R&IM process manages backorders and updates the actor's state at the end of each time bucket.

R&IM_process () {

// effective production is launched according to component availability.

$\overline{X}_i \leftarrow MIN\left(XP_i \;; DL_{j,\theta - l_j} + \bar{I}_j \right)$

// planned release update

$RP_{j,\theta+1} \leftarrow RP_{j,\theta+1} + RP_{j,\theta} - DL_{j,\theta - l_j}$ //lacking components are awaited next time bucket

$RP_{i,\theta + l_i} \leftarrow \overline{X}_i$ //production orders are awaited after the production lead time

// delivery to the customers

$DL_i \leftarrow MIN\left(D_i + I^-_i ; \bar{I}_i + RP_{i,\theta} \right)$

//state of the actor at the end of the time bucket

$\bar{I}_j \leftarrow \bar{I}_j + DL_j - \overline{X}_i$ //components inventory

$\bar{I}_i \leftarrow \bar{I}_i + RP_{i,\theta} - DL_i$ //finished product inventory

$I^-_i \leftarrow I^-_i + D_i - DL_i$ // backorders

}

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