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Impact of the Key Determinants of a Distributed Planning Process on the Performance of a Supply Chain

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In today's highly competitive world, firms try to maximize value for their customers and other stakeholders through the effective management of their supply chains. Given that performance measurement considerably affects the actions of firms' decision makers, it is increasingly important to understand the key factors that can significantly affect the performance of the supply chain. Using analytical models and simulations, this article aims to identify and analyse the key determinants (both financial and nonfinancial) of a distributed planning process that affect the performance of the supply chain. The identified determinants are discussed with respect to three performance dimensions: efficiency, effectiveness, and responsiveness. Our results show that different combinations of the determining factors have varying positive or negative effects on these three performance dimensions.

Keywords: planning process, supply chain management, performance measurement, efficiency, effectiveness, responsiveness

Introduction

Supply chains (SCs) are facing growing pressures due to globalisation, harsh competition, fluctuating energy prices, and volatile financial markets. Their strategic goals aim to reduce costs, improve customer services, increase reliability and efficiency of operations, and perform fast delivery of products to markets. These strategic goals can be achieved by effectively designing, monitoring, and controlling the various processes that constitute the SC. The Supply Chain Operations Reference (SCOR) model enables one to identify the five main processes (plan, source, make, deliver, and return) that

constitute a supply chain. The determinants of each of these processes can affect SC performance.

Many researchers have studied the relationship between the determinants of three of these processes (source, make, and deliver) and supply chain performance, but the determinants of the planning and return processes have not been sufficiently explored. Moreover, the few studies that have been done on this topic are generally limited to manufacturing (Wacker & Sheu, 2006; Olhager & Selldin, 2007) and to the financial aspect of performance (Reiner & Hofmann, 2006).

Christopher (1998, p. 15) defines a supply chain as “the network of organisations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services delivered to the ultimate consumer.” De Man and Burns (2006, p. 2) state that “a supply chain links production units, one unit’s outputs providing inputs into another unit or multiple units.” These production units can be within the same organisation or different organisations within a supply network. This article studies the second case, that is, a supply chain where one organisation’s output provides inputs to another organisation until delivery of the end products to the final customer. In order to maximise the overall performance of the SC and collectively satisfy the ultimate customer, the different companies should plan their production and delivery activities in a distributed, coordinated, and collaborative manner.

This article aims to study how the determinants of a distributed planning process affect the financial and nonfinancial elements of supply chain performance. It is organised as follows. First, a review of the literature enables us not only to develop our research framework but also to formulate our research hypotheses. Then we present the characteristics of the supply chain

studied in this article as well as the mathematical model used to perform some numerical simulations. Subsequently, we present and discuss the results of the simulation. Finally, we draw conclusions, state some limitations and present suggestions for further research.

Literature Review and Hypotheses

A literature review (Arnold & Chapman, 2001; Chase et al., 2004; Handfield & Nichols, 2002; Simchi-Levi et al., 2003; Slack et al., 2007; Stadtler & Kilger, 2000; Stevenson, 2005) enabled us to identify 10 determinants of the planning process (as shown in Table 1): planning horizon, time bucket, frozen time fence, capacity management, lot sizing, inventory management, sequencing, scheduling, forecast accuracy, and cycle time.

These determinants can positively or negatively affect the performance of the SC. Walters (2006) and Rainbird (2004) argue that although the upstream part of the SC emphasises efficiency (which consists of minimising operational costs), the downstream part emphasises effectiveness (which entails an effective response to customer expectations). In other words, the upstream SC tends to be *lean* (efficient) by eliminating wastes whereas the downstream SC tends

to be *agile* (effectively responsive) by providing speedy and accurate response to customer expectations. The expression *effectively responsive* could be broken down into two components: effectiveness (which measures the completeness of the order) and responsiveness (which measures the speed at which the order is delivered).

It follows that a supply chain can be designed, planned, and controlled so as to maximise efficiency, effectiveness, or responsiveness. Many authors (Holweg, 2005; Reichhart & Holweg, 2007; Stevenson & Spring, 2007; Walters, 2006; Zokaei & Hines, 2007) have underlined the vagueness, the multidimensionality, and the interdependency in the definitions of these three performance criteria. For example, as cited by Kritchanchai and MacCarthy (1999, p. 814), Barclay et al. (1996) defined responsiveness as “the ability to react purposefully and within an appropriate timescale to significant events, opportunities or threats (especially from external environment) to bring about or maintain competitive advantage.” This definition implicitly incorporates range and time dimensions just as most definitions of flexibility, such as that given by Slack et al. (2007, p. 39): “the ability to change far enough and fast enough to meet customer requirements.” The multidimensionality of and

Table 1
Determining factors of the planning process.

1. Planning horizon	2. Time bucket	3. Frozen time fence
- Small (e.g., monthly)	- Small (e.g., daily)	- Small (e.g., 1 week)
- Medium (e.g., quarterly)	- Medium (e.g., weekly)	- Medium (e.g., 1 month)
- Large (e.g., yearly)	- Large (e.g., monthly)	- Large (e.g., 1 quarter)
4. Capacity management	5. Lot sizing	6. Inventory management
- Constant output rate	- Lot-for-lot	- Low safety stock
- Chase demand	- Fixed lot size	- Medium safety stock
- Mixed strategy	- Fixed-period quantity	- High safety stock
7. Sequencing	8. Scheduling	9. Forecast accuracy
- Earliest due date	- Forward	- Low confidence
- First in, first out	- Backward	- Medium confidence
- Last in, first out	10. Cycle time	- High confidence
- Longest processing time	- Slow	
- Shortest processing time	- Fast	

interdependence between these performance criteria can be seen explicitly in the following sentences extracted from Sanchez and Pérez (2005, p. 683):

The two most agreed upon dimensions for measuring flexibility of any type are range and response (Gerwin, 1993; Upton, 1994). The range dimension measures the variety of available alternatives for the system adaptation, so that it may continue to operate. This dimension is associated with the system effectiveness and is typically measured by counting the number of options or by a normalised index. The response dimension measures the easiness with which the adaptation can be carried out in terms of the reaction time (or cost) needed to respond to the change that occurred. This dimension may thus be associated with the system efficiency.

Here, responsiveness, efficiency, and effectiveness are all incorporated in flexibility. In this article, we do not intend to review the literature of these terms but simply to adopt a strict and clear definition of each of them, such as to be able to define the various strategies that will be used in our

model. Therefore, we will adopt the following restrictive and one-dimensional (or single factor) definitions:

- *Efficiency* is doing things right (Zokaei & Hines, 2007) and can be defined as the cost of fulfilling customer orders. Although it is generally measured with respect to the best possible way of doing something, some authors define it in relative terms as the best of all possible ways of doing something (Bescos & Dobler, 1995; Halley & Guilhon, 1997; Mas-Colell et al., 1995).
- *Effectiveness* is doing the right thing (Zokaei & Hines, 2007) and can be defined as fulfilling orders exactly as they are requested by customers (that is, the completeness of customer orders).
- *Responsiveness* is doing things quickly and can be defined as the speed at which customer orders are fulfilled.

If leanness is linked to efficiency, agility is linked to effectiveness and responsiveness. When a system aims to achieve a balance between efficiency and effectiveness/responsiveness, it is said to be *leagile*. Naylor et al. (1999, 108) defined leagility as “the combination of the lean and agile paradigms within a

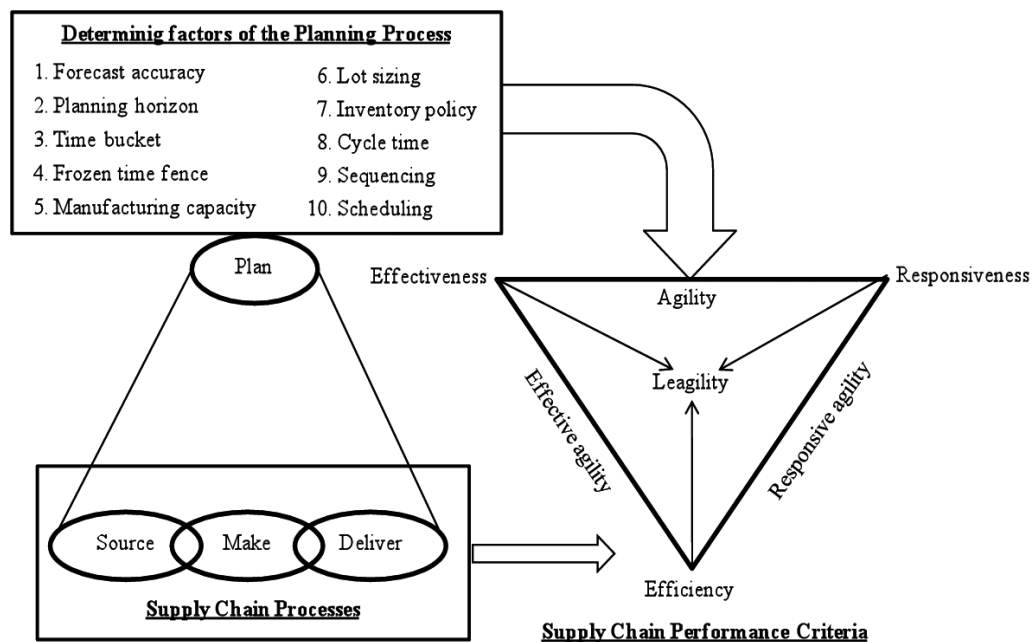
total supply chain strategy by positioning the customer order decoupling point so as to best suit the need for responding to a volatile demand downstream yet providing level scheduling upstream from the decoupling point.” Partial leagility can be achieved by searching for a trade-off between efficiency and effectiveness or between efficiency and responsibility.

Each or a combination of the 10 determinants of the planning process listed in Table 1 could positively or negatively affect performance, thereby leading to different supply chain strategies:

1. Efficiency
2. Effectiveness
3. Responsiveness
4. Agility (effectiveness, responsiveness, and flexibility)
5. Partial effective leagility (efficiency, effectiveness, and flexibility)
6. Partial responsive leagility (efficiency, responsiveness, and flexibility)
7. Leagility (efficiency, effectiveness, responsiveness, and flexibility)

In a nutshell, we can say that these performance dimensions and strategies are based on the

Figure 1
Link between determinants of the planning process and supply chain performance



following supply chain objective: *the supply chain should aim to deliver the right quantity ordered by the customer, at the right time, and at minimum cost.* In this article, we simply use *efficiency* to measure the cost component of this definition, *effectiveness* to measure the “right quantity” component, and *responsiveness* to measure the “right time” component. This framework is represented graphically in Figure 1. It can be used by the planning manager to identify the set of determinants that would enable the achievement of specific performance objectives, depending on the desired supply chain strategy.

Using computer simulations, Robinson et al. (2008) studied eight factors (nonfrozen interval policy, planning horizon length, frozen interval length, re-planning frequency, cycle time length, vendor flexibility, demand range, and demand lumpiness) and arrived at the conclusion that vendor flexibility and its interactions with master production schedule design factors are the most significant drivers of system performance in two-stage supply chains. After studying the effects of four determinants (capacity, storage time, scheduling, and sequencing rules) on the performance of a specific two-stage

system, Akkerman et al. (2007) concluded that, contrary to common sense in operations management, the longest processing time sequencing rule is able to maximise the total production volume per day. Barut (2005) investigated the effectiveness of a tactical demand-capacity management policy to guide decisions in order-driven production systems and found that the dynamic capacity allocation procedure produces higher profit compared to a first-come-first-served policy. Looking at the demand side of a supply network in a configure-to-order environment, Ngaya et al. (2007) studied the impact of three factors (demand skew, demand variability, and configuration capacity) and observed that all the three variables individually and interactively influence customer service performance. From this review of extant literature, we can formulate two hypotheses:

H1: When combined with other determinants, a given determinant of a planning process can positively or negatively affect the performance of a supply chain.

H2: Given that efficiency is often traded off against responsiveness, a given combination of determinants that positively affects the former will negatively affect the latter.

This article aims not only to validate these two hypotheses, but also to find the various combinations of determinants that have a positive or negative effect on one, two, or all three performance dimensions (efficiency, effectiveness, and responsiveness).

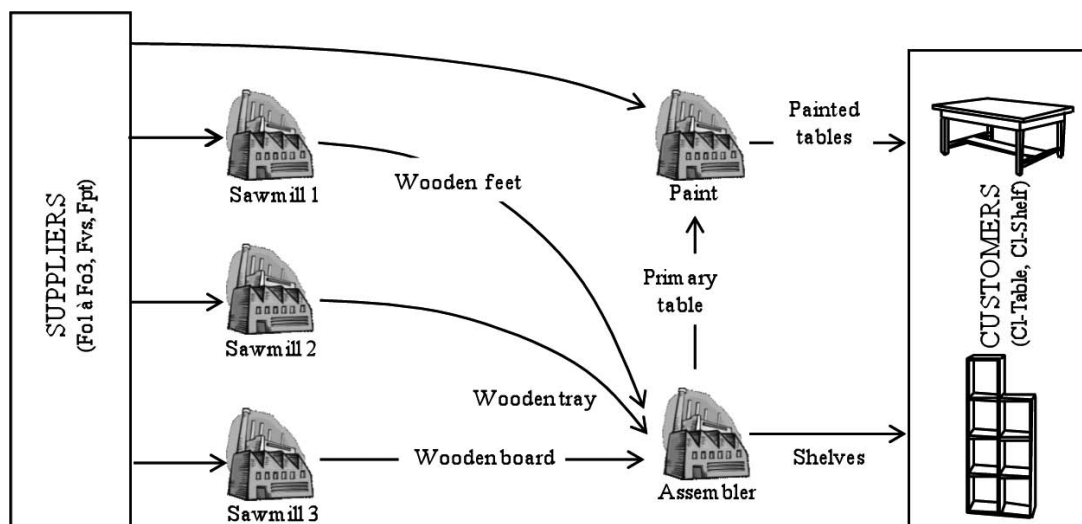
Problem Formulation

In this section, we will present the characteristics of the supply chain studied in this article; the selected determinants that we tested; the three performance metrics that correspond to efficiency, effectiveness, and responsiveness; and the mathematical model used in our simulation.

The supply chain

As shown in Figure 2, this article considers a three-stage multi-products supply chain in a make-to-stock environment, where production is planned based on demand forecasts. Two product groups (shelves and tables) are produced and delivered to end customers. The product structures of the two product groups are simple, with one component at each level. Each stage of the supply chain transforms just one component. At the first stage, we find sawmills, which transform and

Figure 2
The supply chain



deliver wooden parts (table legs, table trays, and shelf boards) to the assembly plant that constitutes the second and final stage for the shelves. After assembly, tables are shipped to a third stage for the painting operation. The sawmills, the assembly plant, and the painting unit are assumed to collaborate in a dyadic supplier-customer relationship. Each plant is considered to be a single resource with a limited capacity. We assume an ideal situation - constant and regular, without shortage - for the supply of raw materials (tree trunks) to the sawmills and the paint plant.

Transport is required between any two plants. Activities and resources needed for transportation are lumped together such that each transport operation is characterized by a given capacity (limiting transfer throughput) and a lead time. Each plant is solely responsible for managing its processes - procurement,

production, and delivery. Planning of operations is jointly done by all the partners. Therefore, the lead time for the transmission of information is zero.

Performance metrics

In section 2, we stated that the performance of the supply chain can be measured using three distinct parameters - efficiency, effectiveness, and responsiveness. We will now define the metrics that will be used to express these parameters.

Efficiency can be measured either in terms of cost or profit margin. An efficient system aims to minimise cost, thereby maximising profit. Because the ultimate goal of the supply chain partners is to make a profit, we will use the profit margin as a metric to measure efficiency. In this study, we will normalise it by taking the highest profit as 100% and then calculating the others with respect to it.

Effectiveness can be measured in terms of the percentage of ordered quantities that are delivered within a given time frame. Its value can go from 0% to 100%. Zero percent means that nothing is delivered on time and 100% means that all the ordered quantities are delivered on time. This performance metric will be referred to as completeness.

Responsiveness can be measured as the normalised average delivery time (NADT) of the total quantity that is delivered. For example, let us consider an order of 100 units of a product to be delivered in week 1 (due date), with a maximum acceptable lateness of 4 weeks beyond the due date. If 40 units are delivered in week 1, 20 in week 2, 10 in week 3, 20 in week 4, and 10 in week 5, responsiveness is equal to 0.65. This is obtained by calculating the NADT as follows:

$$\text{NADT} = [(40 \times 1) + (20 \times 0.75) + (10 \times 0.5) + (20 \times 0.25) + (10 \times 0)] \times 100\%/100 = 65\%$$

Table 2
Notations

PARAMETERS				INDEXES	
H	Planning horizon	CapS _i ^r	Storage capacity	r, r'	Index of PU
K _{p,p'} ^r	Bill of materials coefficients	CapT _i ^{r,r'}	Transport capacity	p, p'	Index of products
DP _p ^r	Production delay	PV _p ^r	Unitary purchase mean cost	t	Index of planning period
DL ^{r,r'}	Transport delay	CA _p ^r	Unitary selling price	H	Horizon
α _p	Quantity of resource required	CS _p ^r	Unitary inventory mean cost		
β _p	Unitary weight or volume	CP _p ^r	Unitary production mean cost	w ₁ , w ₂	Criteria weights
δ _p	Space for stocking a unit p	CB _p ^r	Unitary backorder cost		
CapR _i ^r	Production capacity	CR _p ^r	Unitary shortage cost		
		CT _p ^r	Unitary transport cost		
VARIABLES					
i _{p,t} ^r	Inventory level of product p in the PU _r at the end of period t				
b _{p,t} ^{r,r'}	Amount of products p in the PU _r delivered late for its customer r' at the end of period t				
b _{p,t} ^r	Final customers' backorders of product p in the PU _r at the end of period t				
x _p ^r	Amount of products p never delivered to customer r				
f _{p,t} ^r	Production quantity of product p launched in the PU _r during period t				
d _{p,t} ^{r,r'}	Demand of product p during period t from PU _r to PU _{r'}				
l _{p,t} ^{r,r'}	Delivery quantity of product p launched during period t from PU _r to PU _{r'}				
q _{p,t} ^{r,r'}	Quantity of component p received during period t at the PU _r from PU _{r'}				

Being normalised, the value of responsiveness must be between 0 and 100%, the latter being the best. A value of 100 means that 100% of the ordered quantity was delivered on or before the due date; a value close to 100 signifies that a high percentage of the ordered quantity was delivered on or before the due date and that most of the delivery was done (quickly) within the first period after the due date, whereas a value close to 0 signifies that most of the delivery was done (late) within the last period of the acceptable time frame after the due date.

Mathematical model

The simulation of the planning decision-making process performed by each partner (also called production unit [PU]) in the supply chain is obtained by solving a generic linear programming model. The notations used to describe the model are summarized in Table 2.

The model plans production, inventory levels, replenishment, and delivery according to customers' demand. The cost function or criterion (1) concerns the financial aspect and ensures that the decision-making process is efficient by minimizing costs related to production, inventory, purchased materials, shortages (considered as never delivered at the end of the delivery lead time acceptable to the customer), and backorders (late deliveries).

Constraints (2) represent the evolution of inventory levels. The first constraint concerns the finished products: the quantity resulting from the production at a period t corresponds to a production order released a few periods before (depending on the production lead time DP). The second constraint evaluates the levels of inventory of each component according to the quantities received by suppliers and quantities consumed by production according to coefficients in the bill of materials. Constraint (3) expresses backorders, that is, the difference between the quantity of products requested by customers and the quantity actually delivered. The definition of this expression guarantees the existence of a solution to the planning problem and allows penalising the producer in case of non satisfaction of the customer's order. Constraints (4) represent capacity restrictions for production, stocks, and transportation. The use of an extra capacity for production is allowed but requires higher operational costs. Constraints (5) represent the upper bound of the extra capacity and expressions (7) are non-negativity constraints for all the variables.

Numerical Experiments and Simulation

Table 3 summarises the value of parameters required to test the model.

In section 2, we identified 10 determinants of a planning process. This study being at the exploratory stage, we have chosen to simulate only 5 out of the 10 determinants: sequencing, frozen time fence, capacity management, cycle time, and demand forecast accuracy.

Sequencing is studied through the definition of two rules that characterise how the model intends to satisfy customers when backorders are observed. The first-in-first-out (FIFO) rule corresponds to serving backlogs first before serving recent or incoming customer orders. The last-in-first-out (LIFO) is the opposite rule, which gives higher priorities to current orders rather than serving the backlogs.

The real principle of frozen time fence is not quite simulated. Nevertheless, the decision-making process is dynamically depicted according to the principle of rolling horizon planning: the period of replenishment is defined by a number of elementary periods. By considering different values ($T = 5$ or 10 periods) for the period of replenishment T , we impose the application of planning results on more or fewer periods. This principle is assimilated to the definition of a frozen period, which can affect the supply chain performance.

Two different strategies are considered in the management of the capacity of each partner. The

$$\begin{aligned} \min C_r &= \sum_t \left(\sum_r \sum_{r'} \sum_p (q_{p,t}^{r,r'} \cdot CA_p^r) + \right. \\ &\quad \left. \sum_r (\sum_p i_{p,t}^{r,r'} \cdot CS_p^r + \sum_p (f_{p,t}^r \cdot CP_p^r + b_{p,t}^r \cdot CB_p^r + x_p^r \cdot CR_p^r + l_{p,t}^r \cdot CT_p^r) + y_t^r \cdot AC_t^r) \right) \quad (1) \\ \left\{ \begin{array}{l} i_{p,t}^r = i_{p,t-1}^r + f_{p,t-DP_p^r}^r - \sum_{r'} l_{p,t}^{r,r'} \quad ; \quad i_{p,t}^{r'} = i_{p,t-1}^{r'} + \sum_r q_{p,t}^{r,r'} - \sum_{p'} (K_{p,p'}^r \cdot f_{p,t}^{r,r'}) \quad \forall p, t, r \quad (2) \\ b_{p,t}^{r,r'} = b_{p,t-1}^{r,r'} + d_{p,t}^{r,r'} - l_{p,t}^{r,r'} - x_{p,t}^{r,r'} \quad \forall p, t, r, r' \quad (3) \\ \sum_p \left(\alpha_p \cdot \sum_{\tau=1}^{DP_p^r} f_{p,t-\tau}^r \right) \leq CapR_t^r + y_t^r \quad ; \quad \sum_{p \in P^r} \delta_p \cdot i_{p,t}^r \leq CapS^r \quad ; \quad \sum_{p \in P^r} \beta_p \cdot l_{p,t}^{r,r'} \leq CapT^{r,r'} \quad \forall t, r, r' \quad (4) \\ y_t^r \leq CAP_{SUPP} \quad \forall p, t, r \quad (5) \\ q_{p,t}^{r,r'}, i_{p,t}^r, b_{p,t}^{r,r'}, l_{p,t}^{r,r'}, d_{p,t}^{r,r'}, y_t^r \geq 0 \quad \forall p, t, r \quad (6) \end{array} \right. \end{aligned}$$

Table 3
Main parameters characterizing the SC study case

Suppliers	Production capacity	Added production capacity	Production delay	Unitary production cost	Unitary production cost when using added capacity	Inventory capacity	Inventory cost	Unitary backorder cost
Fo1	no limit	no limit	included in the transport delay	included in sale prices	This cost is equal to once and half the unitary cost defined when no added capacity is required	no limit	not studied	no backorder
Fo2								
Fo3								
Fvs								
Fpt								
Sc1	85	1	1	50000	0.2	0.35		
Sc2	20		2		0.5	3		
Sc3	1200		0.5		0.06	0.2		
Ass	182		4 (Table)		3	4.8		
			5 (Shelf)		1.5	3.6		
Ptr	60	3	8	4	6.8			

PRODUCTS	Quantity of resource required	Unitary weight or volume	Space for stocking one unit	Suppliers
Wood	not studied	3	not studied	Fo1
				Fo2
Screw				Fo3
Painting				Fvs
Wooden feet	1	0.25	1	Fpt
Wooden tray	1	1	1	Sc1
Wooden board	1	0.05	1	Sc2
Primary table	2.6	2	1	Sc3
Shelf	2.6	3	1	Ass
Painted table	1	2	1	

PRODUCTS	CUSTOMERS	Unitary purchase cost	Inventory cost	Transport capacity	Transport delay
Wood	Sc1	50	0.2	no limit	15
	Sc3	50	1		20
	Sc2	50	1.2		10
	Sc3	80	1		5
Screw	Ass	0.1	0.01	3000	5
Painting	Ptr	2	1		5
Wooden feet	Ass	6.5	0.2		2
Wooden tray		70	0.5		2
Wooden board		2.8	0.06		2
Primary table	Ptr	125	3		2
Shelf	40 CI-Shelf	95	unknown		not applicable
Painted table	40 CI-Table	170			

constant output rate strategy consists of calculating the mean demand along the horizon and in defining the production rate as equal to this value. The *chase demand* strategy entails adapting manufacturing capacity to the variation of demand, even if extra capacity is required. We note that the first strategy leads to reducing initial production costs (80% of the

nominal costs given in Table 3), whereas the second is concerned with cost increases (150% of the nominal costs).

The impact of cycle time is also studied through the following principle: the transportation lead time stated in Table 3 represents values corresponding to a long cycle time. In this case, transport is

assumed to be cheap (transport cost = 0.03). In certain cases, customers need to be delivered with short lead times. Short cycle time then leads to reducing by half all the transport lead times. The consequence of reducing cycle time is a higher cost for the service (transport cost = 0.1).

The last determinant studied is the demand forecast accuracy and stability. Two situations are simulated. The first one considers that demand of finished products is not quite stable but is subjected to weak variations. The demand forecast is modified for 10 periods with a maximum amplitude that is equal to 10% (high confidence). However, a low confidence implies that the demand forecast varies over 20 periods with a maximum amplitude of 20%. We note that all variations are not simultaneously observed and are progressively discovered with the rolling horizon principle. The demand variations are shown in Figure 3.

Variations of the studied supply chain are observed to assess the effect of the five previously mentioned determinants on the three performance metrics (profit margin, normalised average delivery time [referred to as NADT and represented by equation 7], and completeness). The profit of each partner is measured in order to assess the financial consequences of these determinants. The customer service level (responsiveness) is measured in terms of NADT. Completeness is measured in terms of the percentage of satisfied orders along the planning horizon (equation (8)).

$$NADT_{p,t,r,r'} = \frac{\sum_{i=0}^5 \frac{5-i}{5} \cdot I_{p,t+i}^{r,r'}}{d_{p,t}^{r,r'}} \quad (7)$$

$$SR_{p,r,r'} = \frac{\sum_H I_{p,t+i}^{r,r'}}{\sum_H d_{p,t}^{r,r'}} \quad (8)$$

Simulation Results and Discussion

By changing the parameters of the determinants each time, we performed 32 simulations. The profit margin, NADT, and completeness were determined for each of the supply chain partners - the three sawmills, the assembly plant, and the painting unit. The total values for each of these three performance metrics were computed for the whole supply chain. In order to keep simple and clear the discussion of our results, we will not present the details for each plant, but only the total values: total profit, total NADT for shelves, total completeness for shelves, total NADT for tables, and total completeness for tables. In order to understand the impact of the various determinants, we sorted the results in a descending order with respect to each of the performance metrics. To clearly emphasise the highly positive and highly negative effects, we report only 8 of the 32 simulations: the first four (highly positive impact) and the last four (highly negative impact). Table 4 shows the ranking by the normalised profit margin.

We observe from this table that the combination of constant output rate and FIFO clearly affects profit positively but NADT negatively. In

Figure 3
Demand variations

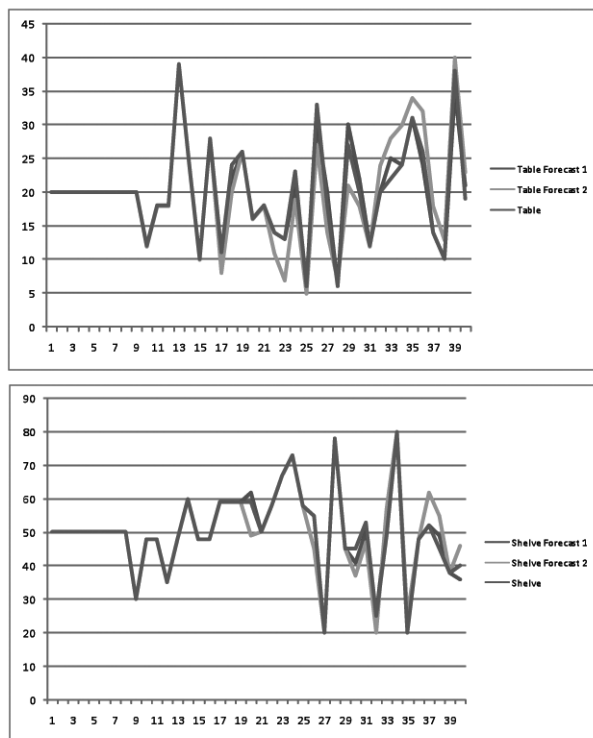


Table 4
Determinant-performance relationship ranked by profit margin

Nature of impact	Serial no.	Period		Capacity management		Sequencing		Cycle time		Forecast accuracy		Total supply chain performance				
		5	10	Constant output rate	Chase demand	LIFO	FIFO	High	Low	High	Low	Profit margin	Shelves		Tables	
													NADT	Complete	NADT	Complete
Positive	38	x		x			x	x			x	100.00	91.95	99.10	98.21	100.00
	6	x		x			x	x		x	100.00	91.95	99.10	98.21	100.00	
	37		x	x			x	x			x	99.98	91.95	99.10	98.62	100.00
	5	x		x			x	x			x	99.98	91.95	99.10	98.62	100.00
Negative	22	x			x		x	x			x	77.42	99.98	100.00	90.99	97.47
	18	x			x	x		x			x	71.23	99.98	100.00	95.13	95.13
	54		x		x		x	x			x	68.00	96.64	97.50	87.16	94.20
	50		x		x	x		x			x	61.47	97.39	97.50	94.35	94.74

other words, this combination of determinants enables the achievement of an efficiency strategy at the expense of responsiveness. This observation confirms our second hypothesis, which states that a given combination of determinants could positively affect one performance criteria while negatively affecting another. It could be deduced that the constant output rate enables the supply chain partners to minimise cost (thereby maximising profit) by not investing in more expensive additional capacity, whereas the FIFO rule penalises NADT because serving backlogs first will increase the average delivery delay.

However, the combination of the chase demand strategy and low demand forecast accuracy affects profit negatively but NADT positively. This combination favours the responsiveness strategy. This is also in line with the second hypothesis. The negative impact on profit is probably due to the additional cost of varying the capacity. We presume that the

adjustment of capacity to follow demand enabled on-time delivery, hence a positive effect on NADT. This probably neutralises the possible negative effect of low forecast accuracy. We note, however, that contrary to what one would expect, there is no clear correlation between the LIFO rule and NADT.

Table 5 shows the ranking by the NADT of the shelves. Here, the combination of chase demand and short planning horizon has a very high positive effect (100%) on NADT and completeness. This achievement of total agility (see supply chain strategy number 4 in section 2) can be explained as a result of the cumulative effect of two factors (chase demand and short planning horizon) that reduce the lapse of time between the receipt of an order and its fulfilment. We note that Table 5 confirms what we have already observed in Table 4, where the combination of constant output rate and FIFO affects NADT negatively but profit positively.

Table 6 shows the ranking by the completeness of the shelves. Just as in Table 5, the combination of chase demand and short planning horizon has a very high positive impact (100%) on NADT and completeness. To a large extent, we can say that low cycle time, which is also a responsiveness driver, has a positive effect on performance criteria. On the contrary and again in line with our second hypothesis, these three determinants negatively affect profit. Quite unlike in the results of the ranking by profit and by NADT, the ranking by completeness does not show a clear negative link between any combination of determinant attributes and the performance criteria. However, looking at the last two worst cases (simulations 50 and 54), we can say that the combination of a long planning horizon, chase demand, high cycle time, and low demand forecast accuracy has an adverse (catastrophic) effect on profit. This is in line with what one would expect from a theoretical perspective because none of the four determinant attributes is an efficiency driver.

Table 5
Determinant-performance relationship ranked by NADT of the shelves

Nature of impact	Serial no.	Period		Capacity management		Sequencing		Cycle time		Forecast accuracy		Total supply chain performance				
		5	10	Constant output rate	Chase demand	LIFO	FIFO	High	Low	High	Low	Profit margin	Shelves		Tables	
													NADT	Complete	NADT	Complete
Positive	19	x			x	x		x	x			82.25	100.00	100.00	99.61	100.00
	23	x			x		x	x				81.54	100.00	100.00	98.51	100.00
	24	x			x		x		x			81.43	100.00	100.00	97.43	100.00
	20	x			x	x		x		x		81.36	100.00	100.00	98.64	100.00
Negative	40		x	x			x			x		97.04	91.95	99.10	98.21	100.00
	8	x		x			x			x		97.04	91.95	99.10	98.21	100.00
	39		x	x			x		x			97.02	91.95	99.10	98.62	100.00
	7	x		x			x		x	x		97.02	91.95	99.10	98.62	100.00

Table 6
Determinant-performance relationship ranked by completeness of the shelves

Nature of impact	Serial no.	Period		Capacity management		Sequencing		Cycle time		Forecast accuracy		Total supply chain performance				
		5	10	Constant output rate	Chase demand	LIFO	FIFO	High	Low	High	Low	Profit margin	Shelves		Tables	
													NADT	Complete	NADT	Complete
Positive	19	x			x	x		x	x			82.25	100.00	100.00	99.61	100.00
	23	x			x		x	x				81.54	100.00	100.00	98.51	100.00
	24	x			x		x		x			81.43	100.00	100.00	97.43	100.00
	20	x			x	x		x		x		81.36	100.00	100.00	98.64	100.00
Negative	35		x	x			x		x			93.47	94.79	97.60	98.70	100.00
	3	x		x			x		x			93.47	94.79	97.60	98.70	100.00
	50		x		x		x			x		61.47	97.39	97.50	94.35	94.74
	54		x		x		x	x		x		68.00	96.64	97.50	87.16	94.20

Figures 4, 5, and 6 show the graphical representations of the three configurations that we have analysed for the shelves. Looking at the three figures we see clearly that the effect of a given determinant attribute changes when it is combined with different other determinant attributes. For example, when chase demand is

combined with short planning horizon, it has a positive effect on NADT, whereas when it is combined with high cycle time, it has a negative effect on completeness. Also, when it is combined with low demand forecast accuracy, it has a negative effect on profit. This observation confirms our first hypothesis.

A similar analysis of the ranking by the NADT of the table product group shows that NADT is positively affected by the combination of LIFO and high demand forecast accuracy. From a theoretical perspective, the downstream part of a supply chain is less vulnerable to the bullwhip effect than the upstream part. Because the painting unit is the last stage of the manufacturing process of the tables, it is therefore not surprising that a high forecast accuracy positively affects NADT, thereby enabling the achievement of the responsiveness strategy. Conversely, FIFO and high cycle time negatively affect NADT. The ranking by completeness of the tables does not show any significant correlation between the determinant attributes and the performance metrics. Almost all the simulations show a completeness of 100%. This may be explained by our argument of the bullwhip effect.

Conclusion and Further Research

The contribution of this article is twofold. First, it develops a framework that would enable the study of the relationship between the determinants of a distributive planning process and the performance (financial and nonfinancial) of a supply chain. Second, using a mathematical model and computer simulations, it shows successfully that different combinations of determinant attributes have either a positive or negative effect on the performance of the supply chain.

The analysis of our simulation results also shows that when there is a trade-off between two parameters (for example, efficiency and responsiveness), a given combination of determinant attributes has opposite effects (positive and negative) on the two performance dimensions.

Though still at the exploratory stage, the results in this article could guide managers in choosing the appropriate combination of determinant attributes that would

Figure 4
Determinant-performance relationship resulting from ranking by profit

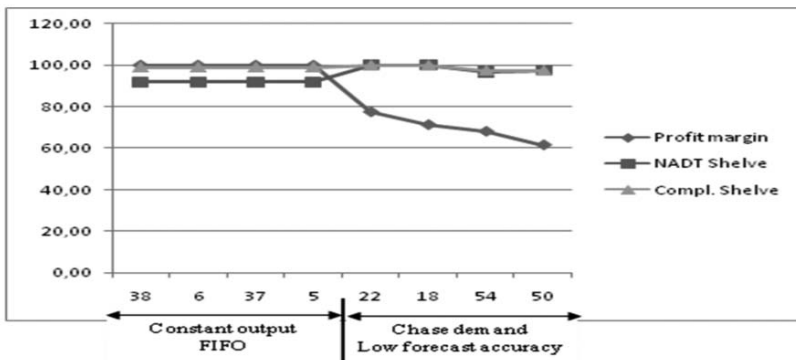


Figure 5
Determinant-performance relationship resulting from ranking by NADT

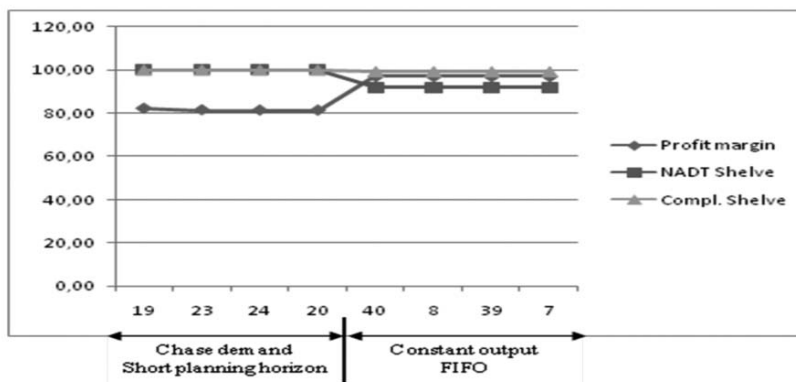
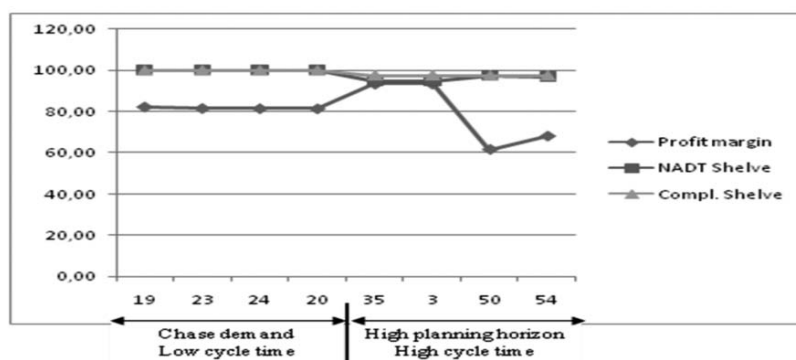


Figure 6
Determinant-performance relationship resulting from ranking by completeness



enable them to achieve their desired supply chain performance objectives. This is to say that at different times and in different market and competitive conditions, managers can pursue different supply chain goals by varying the determinants of the planning process. Our results show how different combinations of determinants enabled the achievement of three different supply chain strategies (efficiency, responsiveness, and agility) out of the seven presented in section 2.

Though these results are quite significant and convincing, more research needs to be done using different data and for different supply chain configurations.

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