Impact of Hybrid Business Models in the Supply Chain Performance

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1. Introduction

Today's manufacturing competition goes beyond single companies and becomes a battle fought between supply chains (Min, 2002), (Nyoman, 2004), meaning the focus has changed from the local manufacturing company to the international supply chain (Olhager, 2003), (Ismail, 2006). In this scenario, competitiveness becomes something holistic about the total supply chain system rather than just what the company entity at the end of the supply chain can offer (Duclos, 2003). Moreover, the service provided to the end customer is determined by the effectiveness and efficiency of the cooperation of all the companies in the supply chain (Terzi, 2004). This trend demands organizations to improve and optimize their supply chain strategies, in order to respond and satisfy customers' demands (Sen, 2004), i.e. to provide end users with the right product at the right place, time, and price (Griffiths, 2000). As the degree of interaction between the members of the supply chain depends on the type of business models used by them (Browne, 1999), the fulfillment of the customer's demands can be achieved through the use of different business models (Sen, 2004). A business model answers who the customer is and what the customer wants, so value can be delivered at an appropriate cost (Chung, 2004). Ngai (2005) offers a value chain-based classification of the different business models used in a supply chain environment: engineer-to-order (ETO), make-to-order (MTO), assembly-to-order (ATO), make-to-stock (MTS), and ship-to-stock (STS). Each typical business model has its advantages and limitations, and only fits for some certain supply chain scenarios (Wadhwa, 2002).

1.1 Hybrid business models

According to Li (2001), a poor supply chain performance can be attributed to a mismatch between the intended market and the business model used to address it. From here the premise that nature of business models must be dynamic: as the current level of competition puts pressure to shift from sales market to customer market (Vonderembse, 2006), a response to a changing market environment (i.e. the market changes in terms of how products win orders in the market place), requires shifting between business models (Olhager, 2003). As this last is not a trivial task, in practice organizations have opted to use hybrid business models. Sen (2004) recognizes the fact that business models cannot be crisply classified as A or B, and that most of the time the complexity of real-life business

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environments force supply chains to use hybrid business models. These hybrid business models are the result of serial/horizontal integration or parallel/vertical integration. In the first case, companies within the supply chain adopt either business model A or business model B, in series. In the second case, companies within the supply chain adopt business model A and business model B, in parallel and in some proportion.
Next section reviews the literature in the area of hybrid business models, while in section three, a quantitative model is offered. In section four, the quantitative model is used to evaluate the influence of these hybrid business models on the performance of the supply chain. Finally, section five presents conclusions and future research.

2. Literature review

Several authors have worked in the past, in the area of business models: Fogarty (1991) called them production positioning strategies, Oden (1993) considered them as methods of response to customer demand, and Hendry (1999) proposed a classification of them. Regarding the use of business models, Hax (1984) proposed customer service and total cost as the criteria to decide between MTS and MTO business models. Hendry (1989) compared MTO and MTS environments with regard to production planning techniques. Guerrero (1991) focused on ATO environments on which component parts are produced according to the forecast demand and assembled into final products based on actual demand. Fumero (1994) proposed a hierarchical planning approach for companies using the ATO business model. Handfield (1995) developed a framework for analyzing time-based strategies in MTO environments. Bilas (1996) discussed the production scheduling in MTO and ATO environments. Caputo (1996) outlined various types of buffers for MTO environments with various types of demand. Dellaert (1996) focused on the lot-sizing problem in a MTO environment. Bridleman (1997) discussed supply chain management and scheduling in MTO environments. Federgruen (1999) dealt with the problem of stochastic economic lot scheduling in mixed MTO and MTS environments. Rajagopalan (2002) provides a heuristic procedure to solve the problem of batch sizes for MTO–MTS environments. Tsubone (2002) states that even though changes in market demand requires organizations to operate under both MTO and MTS environments, there are few studies on the systematic combination of both: authors like Samadhi (1995), Sipper (1997), and Vollman (1997) discuss the differences between them, authors like Williams (1984), Kogan (1998), Nguyen (1998), and New (1995) focus on the issues of combining them, and Soman (2004) presents an elaborate literature review of combined MTO–MTS situations. In general, the main limitation of the past research is that it has focused on improving one business model, or comparing business models to see which performs better under certain circumstances, but have not paid much attention on the integration of business models. Two authors that have addressed this last issue are Li (1999, 2001) and Sen (2004). Next section reviews their work and relates it to our research proposal.

3. Model proposal

In order to evaluate the influence of hybrid business models on the performance of the supply chain, a simulation model was derived (and tested under different operational conditions). We limited our model building effort to the parallel/vertical integration of the MTO and MTS business models.

When market uncertainty is high (in terms of quantity and timing), a MTO business model (where production planning is made on actual orders rather than on forecast) is recommended (Safizadeh, 1997). An MTO business model allows to eliminate finished goods inventories and reduces the firm's exposure to financial risk - as production is initiated until a customer order is received - but usually spells long customer lead times and large order backlogs (Gupta, 2004). As the risk of stockpiling based on un-accurate sales forecasting is avoided by completely precluding building up anticipation stocks, a chase strategy can be used, where the expected demand is tracked and the corresponding capacity is computed, raising it or lowering it accordingly (Buxey, 2003). Safizadeh (1997) suggested that when following a chase strategy, a job shop should be used. A job shop uses general-purpose equipment and a multi-skilled work force (grouped around the process), which provides a high degree of flexibility and capability that allows the profitable manufacturing of low-volumes of customized products. Because of this last is that Li (2001) refers to this business model as a market responsive strategy.

When market uncertainty is low (in terms of quantity and timing), a MTS business model (where production planning is made on forecast rather than on actual orders) is recommended (Safizadeh, 1997). An MTS business model allows to compete in response time - as production of a low variety of stable products is made ahead of demand, kept in stock, and shipped upon receipt of orders (meaning little or no order backlog) - but becomes a) costly, when the number of products is large; and b) risky, when demand is highly variable and/or products have short life cycles (Gupta, 2004). As the reliability of the sales forecasts (and the low variety of stable product produced) reduces the chance of creating obsolete products, a level strategy can be used, where a steady production is maintained and finished goods (smoothing/anticipation) stocks are used to absorb ongoing differences between output and sales (Buxey, 2003). Safizadeh (1997) suggested that when following a level strategy, a continuous production line should be used. A continuous production line uses automated, special-purpose equipment (grouped around the product), which provides a high degree of efficiency and consistent quality that allows the profitable manufacturing of high-volumes of standardized products. Because of this last is that Li (2001) refers to this business model as a physically efficient strategy.

Note: in agreement with Sen (2004), we consider the ATO business model to be essentially the combination of the MTS and MTO environments; i.e. a limited and known variety of products are stocked in a ready-to-assemble condition and assembled to meet the orders. For this reason, the ATO business model is not considered for the hybrid business model analysis.

3.1 Integration ratio X

In order to represent the degree of parallel/vertical integration of these two models, in this paper we introduce the concept of the integration ratio *X*. Li (1999, 2001) considers the expected lead time (ELT) and stock level carrying cost (ESC) of a company, to be dependent on the materials procurement, production, and distribution lead times (SL and PL) and the type of business model used (denoted by the values taken by the variables qsl and qpl shown in Table 1). In order for Table 1 to make sense, the ELT must be understood as an equivalent to the response time, as proposed by Yucesan (2000), the time between the reception of a customer order and the time of delivery:

- In MTO environments, response time is virtually equal to the lead time (assuming that the time between the order receipt and production authorization is negligible).
- In MTS environments, response time is no longer the same as the lead time. Response time can be improved (over lead time), by holding inventory.

ELT =	qsl*SL + qpl*PL
qsl, qpl =>	Type of business model: MTO or MTS
SL =>	lead time from supplier
PL =>	lead time from production
for MTO, ELT =	SL + PL
and,	qsl = 1, qpl = 1
for MTS, ELT =	0 + 0
and,	qsl = 0, qpl = 0

Table 1. Expected lead time of a company using MTO and MTS business models, adapted from Li (2001).

On the other hand, Sen (2004) considers the expected inventory cost (TEI) of an N-partners supply chain, to be dependent on the type of business model used by each partner (denoted by the yn% proportion of MTS and 1- yn% proportion of MTO in Table 2).

TEI =	$\sum_{n=1}^{n=N}$ yn% * MEIn * bn * T
yn% =>	proportion of MTS business model
MEIn =>	mean expected inventory at nth partner
Bn =>	inventory cost per unit at nth partner
T =>	time period of planning
for MTS, yn% =	1
for MTO, yn% =	0

Table 2. Expected inventory cost of a supply chain using hybrid business models, adapted from Sen (2004).

When qsl, qpl, and yn% are compared, we notice that they play a similar role in the description of the hybrid business model. In this paper we retake this idea, and propose to represent the business model proportionality through the use of an integration ratio *X*. It must be noted that neither Li or Sen offers an explanation of the meaning of the business model proportionality. In our case, the integration ratio *X* can be understood as an indicator of the level of customer feedback and therefore, of the uncertainty of what to do next, when to do it, and for how long, as shown in Table 3: when the integration ratio *X* = 1, then the hybrid business model is a pure MTO and all the activities are driven by customer's information (the uncertainty of what, when, and for how long is at its maximum, so a waiting time for instruction is required and no planning ahead of time – like building inventory - can take place); when the integration ratio *X* = 0, then the hybrid business model is a pure MTS and all the activities are driven by forecast information (the uncertainty of what, when, and for how long is at its minimum, so a waiting time for instruction is not required and planning ahead of time – like building inventory - can take place). This reasoning is consistent with the formulas in Tables 1 and 2.

SUBCYCLES	ACTIVITIES	S1 = info from customer; S2 = info from forecast	
		MTO	MTS
Supply	Make versus buy decisions	S1	S2
	Identify, evaluate, and develop suppliers	S1	S2
	Negotiate terms for quantity, quality, delivery, and price	S1	S2
	Release orders for materials, and components	S1	S2
	Release orders for tooling	S1	S2
	Monitor suppliers to ensure compliance with terms	S1	S2
Production	Production planning and control	S1	S2
	Materials management	S1	S2
	Fabricate parts	S1	S2
	Assemble products	S1	S2
	Inspection, testing, rework	S1	S2
	Inventory finished products	N/A	S2
Distribution	Ship products to distribution center	N/A	S2
	Pick products for customer orders	S1	S2
	Ship products and invoice customers	S1	S1

Table 3. Source of customer feedback for MTO and MTS business models, adapted from Miltenburg (1996).

3.2 Simulation model structure

The analyzed supply chain is linear, with four partners serially connected, and with partner i using and hybrid business model that is X_i percentage of MTO (Figure 1). Two are the supply chain performance criteria: total response time (given by the sum of the response times of partner i during period j of the planning period T), and total backlog (given by the accumulated backlog of partner 1, at the end of planning period T).

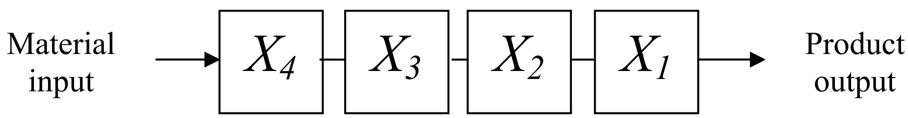

Figure 1. The serial supply chain with hybrid business models

The main differences between our proposal and Li's and Sen's work are the following:

- Li's work mainly focus on analyzing the cost/time impact of MTO, ATO, and MTS as standalone business models and not part of a supply chain (as we propose).
- Sen's work mainly focus on the cost impact of hybrid business model within a supply chain, but not the time and inventory impact (as we propose).

For the purpose of quantitatively analyzing the impact of various degrees of business model integration ratios on the supply chain performance (i.e. total response time, total backlog), a systems dynamics (SD) simulation model was built - using the simulation software iThink (1996) – and used to test a series of different scenarios. SD is a system thinking approach that a) is not data driven, b) targets the top management levels, and c) focuses on how the structure of a system and the taken policies affect its behavior (Eskandari, 2007). For this reason, the SD model presented in this paper can be considered a second order model - in contrast to first order models that are used for theory testing (Larsen, 2002) - a research instrument for theory development rather than a tool for assisting decision-making (Adamides, 2006). The simulation model was verified and validated following a similar approach to the one in Hwarng (2005): the model was presented to experienced professionals in the area of simulation model building, the simulation model output was examined for reasonableness under a variety of settings of input parameters, i.e. the lead times of each supply chain partner were set to some known deterministic value, and later the simulation model output was compared with manual calculations (finding no discrepancies between the simulation and manual calculations). Figure 2 shows the SD simulation model. The most important assumptions made in the simulation model are the following:

- *Backlog* P_i is the difference between *demand* P_i and *supply* P_i, during period *j* of the planning period T.
- *Demand* P_i varies according to a normal distribution, with a mean of 100 units and a standard deviation of *uncertainty* $_i$. The normal distribution is used to represent a symmetrically variation above and below a mean value (Banks, 2000).
- *Uncertainty* $_i$ ranges from 0 (low) to 20 (high).
- *Demand* P_i is transmitted without distortion to supply chain partner P_{i+i}. This means that *demand* $P_1 = P_2 = P_3 = P_4$.
- Supply P_i is equal to supply P_i OUT.
- Supply P_i OUT is equal to Supply P_i IN after a delay of lead time P_i.
- *Lead time* P_i varies according to a normal distribution (see Table 4). Lead time is given in weeks.
- *Supply* P_i *IN* is the sum of the contribution made by *inventory* P_i and *capacity* P_i. This is done with the intention to reflect the different demand fulfillment strategies, i.e. level strategy (inventory-oriented) for MTS environments and chase strategy (capacity-oriented) for MTO environments.
- *Business model* P_i ranges from 0 (MTS environment) to 1 (MTO environment).
- *Inventory* P_i is equal to:

$$\text{supply } P_{i+1} * (1 - \text{business model } P_i) * (1 - (\text{uncertainty }_i / 20))$$

  In this way, when *uncertainty* $_i$ is low (0) and *business model* P_i is 0 (MTS environment), all the contribution to *supply* P_i *IN* comes from *inventory* P_i (as established by a level strategy), and is equal to the input from *supply* P_{i+1}.

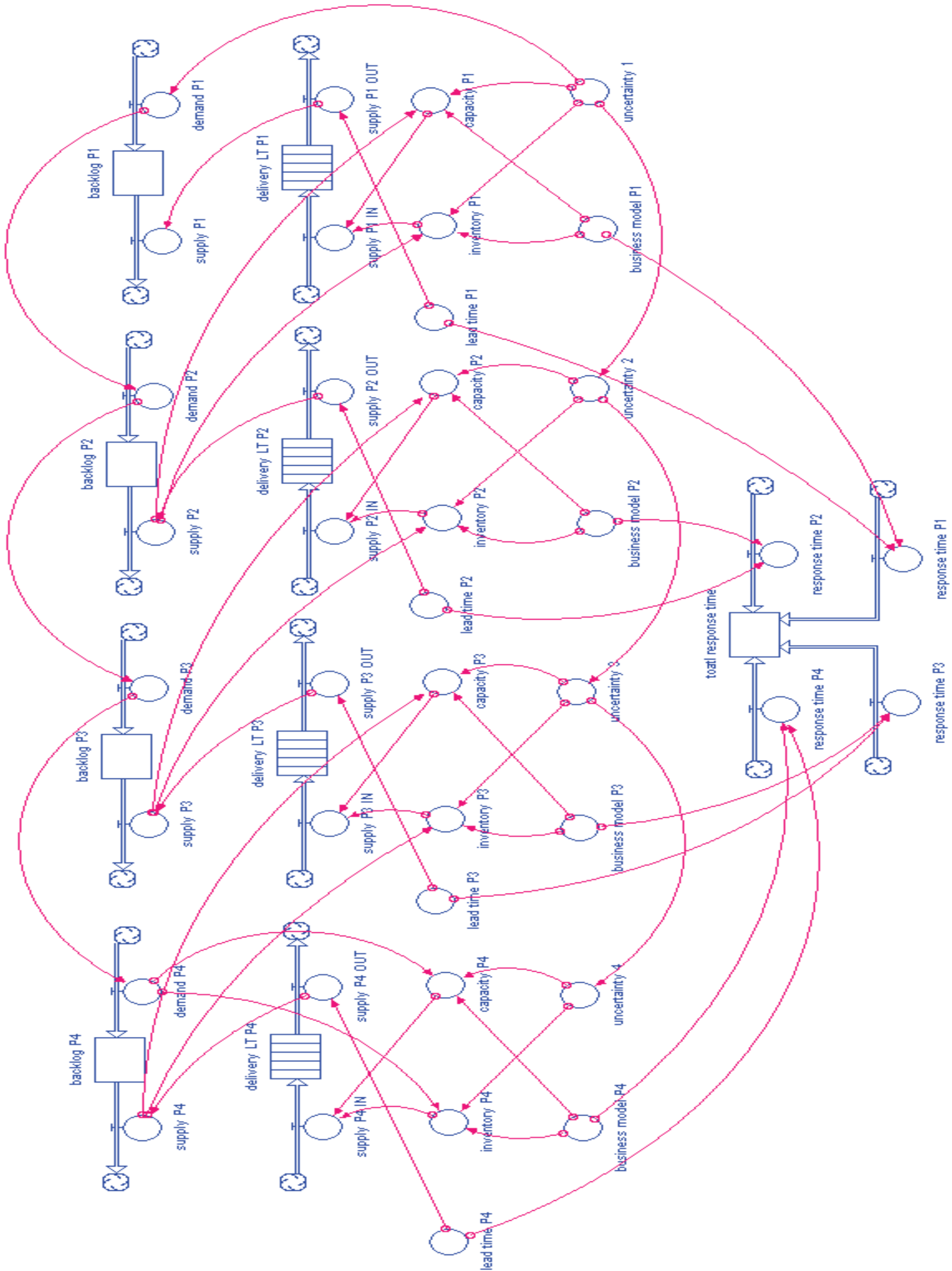

Figure 2. SD simulation model of the serial supply chain with hybrid business models

- Capacity Pi is equal to:

$$\text{supply } P_{i+1} * (\text{business model } P_i) * (\text{ uncertainty }_i / 20)$$

In this way, when *uncertainty* $_i$ is high (1) and *business model* P_i is 1 (MTO environment), all the contribution to *supply* P_i *IN* comes from *capacity* P_i (as established by a chase strategy), and is equal to the input from *supply* P_{i+1}.

- Response time P_i is equal to:

$$\text{lead time } P_i * \text{business model } P_i$$

In this way, when *business model* P_i is 1 (MTO environment), the response time is equal to the lead time (as established in section 3.1).

4. Sensitivity analysis

Experiments consisted of testing several scenarios to collect statistical data on the supply chain TT. Initially, 414 different scenarios were tested (with planning period T = 30) and 30 replications per scenario were used to build confidence intervals of 95% level. The rest of this section analyzes the results presented on Tables 6 through 13. The scenarios tested were:

- The effect of varying the level of demand uncertainty and lead time variation (Table 4).
- The effect of varying *X* and the number of partners using the *X* conditions (Table 5).

Demand variation	**P1**	**P2**	**P3**	**P4**
Scenario 1: high variation	100 + Normal (0, 20)			
Scenario 2: medium variation	100 + Normal (0, 10)			
Scenario 3: low variation	100 + Normal (0, 0)			
Lead time variation	**P1**	**P2**	**P3**	**P4**
Scenario 1: low variation	Normal (2, 0)	Normal (1, 0)	Normal (5, 0)	Normal (3, 0)
Scenario 2: medium variation	Normal (2, 0.25)	Normal (1, 0.25)	Normal (5, 0.25)	Normal (3,0.25)
Scenario 3: high variation	Normal (2, 0.5)	Normal (1, 0.5)	Normal (5, 0.5)	Normal (3, 0)

Table 4. Mean values of the supply chain operational conditions

Combinations	Compossitions			
	X = **1**	X = **0.6**	X = **0.3**	X = **0.0**
1	P1P2P3P4	N/A	N/A	N/A
2	P1P2P3	P4	P4	P4
3	P1P2P4	P3	P3	P3
4	P1P3P4	P2	P2	P2
5	P2P3P4	P1	P1	P1
6	P1P2	P3P4	P3P4	P3P4
7	P1P3	P2P4	P2P4	P2P4
8	P1P4	P2P3	P2P3	P2P3
9	P2P3	P1P4	P1P4	P1P4
10	P2P4	P1P3	P1P3	P1P3
11	P3P4	P1P2	P1P2	P1P2
12	P1	P2P3P4	P2P3P4	P2P3P4
13	P2	P1P3P4	P1P3P4	P1P3P4
14	P3	P1P2P4	P1P2P4	P1P2P4
15	P4	P1P2P3	P1P2P3	P1P2P3
16	N/A	P1P2P3P4	P1P2P3P4	P1P2P3P4

Table 5. Supply chain combinations and compositions

4.1 Simulation results: lead time variation analysis

For scenarios 1-3 and combinations 1-16, as *X* decreases (left to right), the total response time values decrease (see Table 6). This is because each partner's hybrid business model tends to be a pure MTS, where all the activities are driven by forecast information. For scenarios 1-3, highest total response time values are found:

- For combinations 2-5, when P2 decreases its *X* (combination 4).
- For combinations 6-11, when P1 and P2 decrease their *X* (combination 11).
- For combinations 12-15, when P1, P2, and P4 decrease their *X* (combination 14).

This can be explained as follows: P2 and P1 have the first and second shortest lead time values (Table 5), so reducing them have a low impact on the total response time value.

- For scenarios 1-3, lowest total response time values are found: For combinations 2-5, when P3 decreases its *X* (combination 3).
- For combinations 6-11, when P3 and P4 decrease their *X* (combination 6).
- For combinations 12-15, when P1, P3, and P4 decrease their *X* (combination 13).

This can be explained as follows: P3 and P4 have the first and second largest lead time values (Table 5), so reducing them have a big impact on the total response time value.

Scenario 1: low lead time variation					Scenario 2: medium lead time variation					Scenario 3: high lead time variation				
Combination	X = 1	X = 0.6	X = 0.3	X = 0.0	Combination	X = 1	X = 0.6	X = 0.3	X = 0.0	Combination	X = 1	X = 0.6	X = 0.3	X = 0.0
1	11	N/A	N/A	N/A	1	11.05	N/A	N/A	N/A	1	11.09	N/A	N/A	N/A
4	P1P3P4	10.6	10.3	10	4	P1P3P4	10.72	10.36	10.11	4	P1P3P4	10.68	10.14	9.97
5	P2P3P4	10.2	9.6	9	5	P2P3P4	10.27	9.68	8.89	5	P2P3P4	10.34	9.77	9.06
2	P1P2P3	9.8	8.9	8	2	P1P2P3	9.72	8.79	7.97	2	P1P2P3	9.68	8.90	7.91
3	P1P2P4	9	7.5	6	3	P1P2P4	8.22	7.36	5.94	3	P1P2P4	8.91	7.44	5.58
11	P3P4	9.8	8.9	8	11	P3P4	9.76	9.06	7.94	11	P3P4	9.71	8.93	7.78
7	P1P3	9.4	8.2	7	7	P1P3	9.42	8.36	6.99	7	P1P3	9.33	8.41	6.83
9	P2P3	9	7.5	6	9	P2P3	8.85	7.52	5.99	9	P2P3	9.01	7.54	5.92
8	P1P4	8.6	6.8	5	8	P1P4	8.50	6.81	5.05	8	P1P4	8.21	6.82	5.00
10	P2P4	8.2	6.1	4	10	P2P4	8.19	6.16	3.98	10	P2P4	8.10	6.25	3.96
6	P1P2	7.8	5.4	3	6	P1P2	7.76	5.31	3.06	6	P1P2	7.78	5.44	2.88
14	P3	8.6	6.8	5	14	P3	8.49	6.78	5.17	14	P3	8.76	6.76	4.90
15	P4	7.8	5.4	3	15	P4	7.86	5.39	2.98	15	P4	7.74	5.47	2.86
12	P1	7.4	4.7	2	12	P1	7.33	4.96	1.96	12	P1	7.26	4.73	1.95
13	P2	7	4	1	13	P2	7.03	4.04	1.05	13	P2	7.17	3.96	1.14
16	N/A	6.6	3.3	0	16	N/A	6.75	3.39	0	16	N/A	6.51	3.35	0

	Higher values		Lower values

Table 6. Total response time

When compared the total response time values of scenarios 1, 2, and 3, we found that (see Table 7):

- As uncertainty increases (scenarios 1 vs. scenario 2 vs. scenario 3) more MTO-oriented hybrid business models should be preferred by the supply chain partners, as they allow the market responsive strategy required by the unpredictability of the firms' environment. We can see how as the uncertainty increases and the number of partners using a pure MTO business model decreases, the % of time shorter response time values are found also decreases.

	Lead time variation variation	
Combination	**Medium (Scenario 2)**	**High (Scenario 3)**
1	0	0
2-5	58.33	66.66
6-11	55.55	61.11
12-15	50	58.33
16	0	50

Table 7. Percentage of time lower total response time values are found, when compared to scenario 1 (low lead time variation)

			FREQUENCY OF:											
			COMBINATIONS					**SCENARIOS**			**X**			
Response time value	**Frecuency**	%	**1**	**2-5**	**6-11**	**12-15**	**16**	**L_{LT}**	**M_{LT}**	**H_{LT}**	**1**	**0.6**	**0.3**	**0.0**
11+	3	2.15	1					1	1	1	3			
10-11	11	7.91		2				4	4	3		6	3	2
9-10	20	14.38		4	3			6	5	6		13	4	3
8-9	23	16.54		3	5	1		5	8	7		10	9	4
7-8	22	15.82		2	4	3		3	6	8		12	6	4
6-7	17	12.23		1	4	1	1	6	5	5		3	9	4
5-6	15	10.79		1	3	2		4	6	5			6	9
4-5	7	5.03			1	3		3	2	2			5	2
3-4	9	6.47			2	2	1	3	3	3			4	5
2-3	4	2.87			1	3		1	1	2				4
1-2	5	3.59				2		1	2	2				5
0-1	3	2.15					1	1	1	3				3
Frecuency %			1.75	22.80	40.35	29.82	5.26	29.45	34.10	36.43	2.17	31.88	33.33	32.60

Table 8. Total response time, ordered from higher to lower values

When ordered the total response time values, from higher to lower values (Table 8), we notice that:

- The response time values in the brackets of 8-9 weeks and 7-8 weeks are the first and second place in frequency (16.54% and 15.82%).

- Combinations 6-11 are the most frequent (40.35%) and heavily influence the response time values in the 8-9 and 7-8 brackets.
- Scenario 3 (high lead time variation) is the most frequent (36.43%), and heavily influences the response time values in the 8-9 and 7-8 brackets.
- Integration ratio X = 0.3 is the most frequent (33.33%) and heavily influences the response time values in the 8-9 and 7-8 brackets.

From these results, it can be concluded that the same results (in terms of total response time values) can be achieved by allowing the supply chain partners to manage their operations on their own way without imposing a specific business model. For example, by having at most two supply chain partners using a pure MTO business model (i.e. combinations 6-11) and allowing the rest of the partners to operate under certain conditions (i.e. composition X = 0.3), the uncertainty present in the system (high lead time variation, scenario 3) can be handled in a way that the total response time value can be reduced up to 36.36% (from 11+ weeks to 7 weeks).

4.2 Simulation results: demand variation analysis

For scenarios 1-2, combinations 1-16, and low to high lead time variation, as X decreases (left to right), the total backlog values increase (Tables 9, 10, and 11). This is because each partner's hybrid business model tends to be a pure MTS, where a level strategy (inventory-oriented) is followed (not the most appropriate when demand uncertainty is present).

In the case of scenario 3, combinations 1-15, and low to high lead time variation, as X decreases (left to right), the total backlog value remains the same (3000). This is because as long as there is one supply chain partner (using a pure MTO business model) in a low demand uncertainty environment, its contribution to the backlog downstream the supply chain will be zero (see the expression for *Capacity* P_i, in section 3.2). The value of 3000 is then the result of 100 units per period j during a planning period T = 30.

In the case of scenario 3, combination 16, and low to high lead time variation, as X decreases (left to right), the total backlog value decrease. This is because in a low demand uncertainty environment, a level strategy (inventory-oriented) performs better than a chase strategy (capacity-oriented). For scenarios 1-2, and low to high lead time variation, highest total backlog values are found:

- For combinations 2-5, when P3 decreases its X (combination 3).
- For combinations 6-11, when P3 and P4 decrease their X (combination 6).
- For combinations 12-15, when P1, P3, and P4 decrease their X (combination 13).

This can be explained as follows: as stated before, in environments where demand uncertainty is present, as each partner's hybrid business model tends to be a pure MTS (X decreasing), the total backlog value increases because the level strategy (inventory-oriented) followed is not the most appropriate. If we take into account that P3 and P4 have the first and second largest lead time values (Table 5), this increasing effect (on the total backlog value) lasts longer. The opposite is observed for scenarios 1-2, and low to high lead time variation, where the lowest total backlog values are found:

- For combinations 2-5, when P2 decreases its X (combination 4).
- For combinations 6-11, when P1 and P2 decrease their X (combination 11).
- For combinations 12-15, when P1, P2, and P4 decrease their X (combination 14).

Scenario 1: high demand variation					**Scenario 2: medium demand variation**					**Scenario 3: low demand variation**				
Combination	X = **1**	X = **0.6**	X = **0.3**	X = **0.0**	**Combination**	X = **1**	X = **0.6**	X = **0.3**	X = **0.0**	**Combination**	X = **1**	X = **0.6**	X = **0.3**	X = **0.0**
1	1080.8	N/A	N/A	N/A	1	2925.8	N/A	N/A	N/A	1	3000	N/A	N/A	N/A
3	P1P2P4	1841.23	2561.95	3052.77	3	P1P2P4	2940.74	2974.09	2979.82	3	P1P2P4	3000	3000	3000
2	P1P2P3	1782.13	2440.25	3031.86	2	P1P2P3	2930.15	2963.02	2965.43	2	P1P2P3	3000	3000	3000
5	P2P3P4	1779.91	2374.54	3022.3	5	P2P3P4	2864.1	2877.72	2948.52	5	P2P3P4	3000	3000	3000
4	P1P3P4	1752.52	2348.79	2907.12	4	P1P3P4	2822.42	2851.88	2879.43	4	P1P3P4	3000	3000	3000
6	P1P2	2390.14	2973.91	3124.48	6	P1P2	2934.41	2992.09	3129.19	6	P1P2	3000	3000	3000
10	P2P4	2367.28	2927.9	3074.45	10	P2P4	2901.65	2949.65	3093.2	10	P2P4	3000	3000	3000
8	P1P4	2361.47	2885.11	3008.49	8	P1P4	2865.19	2923.08	2993.01	8	P1P4	3000	3000	3000
9	P2P3	2358.58	2875.96	2997.03	9	P2P3	2861.16	2880.68	2960.43	9	P2P3	3000	3000	3000
7	P1P3	2325.07	2858.14	2949.11	7	P1P3	2765.64	2851.98	2900.25	7	P1P3	3000	3000	3000
11	P3P4	2205.9	2838.58	2928.76	11	P3P4	2690.14	2773.79	2888.25	11	P3P4	3000	3000	3000
13	P2	2724.79	2970.61	3170.36	13	P2	2899.68	3015.26	3036.74	13	P2	3000	3000	3000
12	P1	2696.9	2913.99	3097.95	12	P1	2872.73	2881.96	2898.16	12	P1	3000	3000	3000
15	P4	2635.31	2905.54	3066.75	15	P4	2867.91	2874.32	2887.1	15	P4	3000	3000	3000
14	P3	2576.37	2873.72	3030.06	14	P3	2847.76	2866.05	2882.96	14	P3	3000	3000	3000
16	N/A	2737.35	2989.16	3151.41	16	N/A	2838.06	2866.27	2870.32	16	N/A	2951.4	2543.8	1100

Higher values | Lower values

Table 9. Total backlog, low lead time variation

Scenario 1: high demand variation					Scenario 2: medium demand variation					Scenario 3: low demand variation				
Combination	**X = 1**	**X = 0.6**	**X = 0.3**	**X = 0.0**	**Combination**	**X = 1**	**X = 0.6**	**X = 0.3**	**X = 0.0**	**Combination**	**X = 1**	**X = 0.6**	**X = 0.3**	**X = 0.0**
1	1006.5	N/A	N/A	N/A	1	2948.5	N/A	N/A	N/A	1	3000	N/A	N/A	N/A
3	P1P2P4	1918.53	2368.22	3066.3	3	P1P2P4	2956.49	2986.23	3120.53	3	P1P2P4	3000	3000	3000
2	P1P2P3	1908.07	2366.52	3005.25	2	P1P2P3	2917.79	2977.29	2993.22	2	P1P2P3	3000	3000	3000
5	P2P3P4	1766.97	2335.81	2998.61	5	P2P3P4	2889.98	2904.11	2970.48	5	P2P3P4	3000	3000	3000
4	P1P3P4	1752.37	2292.75	2745.44	4	P1P3P4	2779.37	2893.02	2937.61	4	P1P3P4	3000	3000	3000
6	P1P2	2432.95	2933.35	3064.35	6	P1P2	2883.91	2961.17	3082.81	6	P1P2	3000	3000	3000
10	P2P4	2356.86	2894.33	3028.69	10	P2P4	2844.13	2901.58	3039.58	10	P2P4	3000	3000	3000
8	P1P4	2274.22	2875.29	2947.94	8	P1P4	2814.26	2898.11	2924.77	8	P1P4	3000	3000	3000
9	P2P3	2212.64	2850.64	2930.69	9	P2P3	2814.01	2893.23	2921.52	9	P2P3	3000	3000	3000
7	P1P3	2202.15	2812.8	2911.94	7	P1P3	2803.85	2805.04	2900.05	7	P1P3	3000	3000	3000
11	P3P4	2097.17	2778.84	2906.48	11	P3P4	2752.19	2768.07	2863.77	11	P3P4	3000	3000	3000
13	P2	2696.47	2932.79	3223.23	13	P2	2899.88	2982.19	3028.82	13	P2	3000	3000	3000
12	P1	2635.7	2917.14	3203.85	12	P1	2859.02	2926.09	2942.66	12	P1	3000	3000	3000
15	P4	2621.63	2891.91	3064.13	15	P4	2850.35	2883.97	2893.97	15	P4	3000	3000	3000
14	P3	2579.89	2879.55	2982.3	14	P3	2844.3	2871.43	2888.72	14	P3	3000	3000	3000
16	N/A	2728.46	3092.83	3121.16	16	N/A	2873.69	2910.99	2959.37	16	N/A	2951.4	2543.8	1100

Higher values (red) | Lower values (blue)

Table 10. Total backlog, medium lead time variation

Scenario 1: high demand variation					Scenario 2: medium demand variation					Scenario 3: low demand variation				
Combination	X = 1	X = 0.6	X = 0.3	X = 0.0	Combination	X = 1	X = 0.6	X = 0.3	X = 0.0	Combination	X = 1	X = 0.6	X = 0.3	X = 0.0
1	1170.3	N/A	N/A	N/A	1	2918.4	N/A	N/A	N/A	1	3000	N/A	N/A	N/A
3	P1P2P4	1986.17	2540.96	3082.34	3	P1P2P4	2927.17	2947.6	3101.93	3	P1P2P4	3000	3000	3000
2	P1P2P3	1828.18	2457.84	2957.05	2	P1P2P3	2841.95	2932.1	3018.21	2	P1P2P3	3000	3000	3000
5	P2P3P4	1798.92	2453.21	2943.69	5	P2P3P4	2840.24	2919.5	2932.2	5	P2P3P4	3000	3000	3000
4	P1P3P4	1791.96	2387.85	2909.54	4	P1P3P4	2819.95	2835.5	2861.37	4	P1P3P4	3000	3000	3000
6	P1P2	2418.87	2961.09	3085.43	6	P1P2	2921.01	3089.2	3096.44	6	P1P2	3000	3000	3000
10	P2P4	2380.29	2897.14	3064.43	10	P2P4	2887.96	2954.2	2984.96	10	P2P4	3000	3000	3000
8	P1P4	2371.82	2885.71	3036.18	8	P1P4	2868.81	2937.3	2980.81	8	P1P4	3000	3000	3000
9	P2P3	2333.06	2850.06	2986.75	9	P2P3	2830.17	2905.9	2942.19	9	P2P3	3000	3000	3000
7	P1P3	2303.92	2842.92	2962.46	7	P1P3	2763.5	2875	2906.44	7	P1P3	3000	3000	3000
11	P3P4	2265.1	2799.69	2891.18	11	P3P4	2749.52	2794.9	2874.44	11	P3P4	3000	3000	3000
13	P2	2693.96	2945.65	3131.87	13	P2	2939.11	3027.4	3209.06	13	P2	3000	3000	3000
12	P1	2657.68	2919.53	3073.6	12	P1	2870.83	2970.9	2927.15	12	P1	3000	3000	3000
15	P4	2544.8	2896.29	2979.34	15	P4	2850.02	2888.5	2922.7	15	P4	3000	3000	3000
14	P3	2415.43	2871.72	2946.77	14	P3	2845.29	2871.4	2875.52	14	P3	3000	3000	3000
16	N/A	2651.8	2961.52	3088.74	16	N/A	2900.06	2945.7	2946.74	16	N/A	2951.4	2543.8	1100

Higher values | Lower values

Table 11. Total backlog, high lead time variation

In this case, P2 and P1 have the first and second shortest lead time values (Table 5), so their increasing effect (on the total backlog value) don't last much. When compared the total backlog values of scenarios 1, 2, and 3, and low lead time variation, we found two things (see Table 12):

- Regarding demand variation; as uncertainty decreases (scenarios 1 vs. scenario 2 vs. scenario 3) more MTS-oriented hybrid business models should be preferred by the supply chain partners, as they allow the physically efficient strategy fitted for a forecast-driven environment. We can see how as the uncertainty decreases, and the number of partners using a pure MTS business model increases, the % of time lower total backlog values are found also increases.
- Regarding lead time variation; as uncertainty increases (Table 9 vs. Table 10 vs. Table 11) more MTO-oriented hybrid business models should be preferred by the supply chain partners, as they allow the market responsive strategy required by the unpredictability of the firms' environment. We can see how as the uncertainty increases and the number of partners using a pure MTO business decreases (i.e., combination 2-5 of Table 9 vs. combination 2-5 of Table 10 vs. combination 2-5 of Table 11), the % of time lower total backlog values found also decreases (or remain the same).

Lead time variation		Demand variation	
	Combination	Medium (Scenario 2)	Low (Scenario 3)
Low (Table 9)	1	0	0
	2-5	33.33	25
	6-11	33.33	16.66
	12-15	58.33	33.33
	16	66.66	66.66
Médium (Table 10)	1	0	0
	2-5	25	16.66
	6-11	33.33	16.66
	12-15	50	25
	16	66.66	66.66
High (Table 11)	1	0	0
	2-5	16.66	8.33
	6-11	33.33	16.66
	12-15	41.66	16.66
	16	66.66	66.66

Table 12. Percentage of time lower total backlog values are found, when compared to scenario 1 (high demand variation)

When ordered the total backlog values, from higher to lower values (Table 13), we notice that:

- The total backlog values in the brackets of 3000+ and 2800-3000 units are the first and second place in frequency (41.16% and 39.95%).
- Combinations 6-11 are the most frequent (37.28%) and heavily influence the total backlog values in the 3000+ and 2800-3000 brackets..

Backlog value	Frecuency	%	FREQUENCY OF:														
			COMBINATIONS					SCENARIOS						X			
			1	**2-5**	**6-11**	**12-15**	**16**	**L_D**	**M_D**	**H_D**	**L_{LT}**	**M_{LT}**	**H_{LT}**	**1**	**0.6**	**0.3**	**0.0**
3000+	170	41.16	3	47	60	58	2	129	14	27	1	1	1	3	43	45	79
2800-3000	165	39.95	3	37	66	48	11	3	114	48	1	1	1	3	40	76	46
2600-2800	23	5.56		2	11	8	2		9	14	1	1	1		17	5	1
2400-2600	14	3.38		6	1	4	3	3		11	1	1	1		6	8	
2200-2400	23	5.56		7	15					22	1	1	1		15	7	
2000-2200	0	0													1		
1800-2000	4	0.96		4						4	1	1	1		4		
1600-1800	7	1.69		7						7	1	1	1		7		
1400-1600	0	0															
1200-1400	0	0															
1000-1200	7	1.69	2	2			3	3		4	1	1	1	3	1		3
Frecuency %			**1.93**	**27.11**	**37.28**	**28.57**	**5.08**	**33.74**	**33.49**	**32.76**	**33.33**	**33.33**	**33.33**	**2.17**	**32.44**	**34.14**	**31.23**

Table 13. Total backlog, ordered from higher to lower values

- Scenarios 1, 2, and 3 (low, medium, and high demand variation) influence equally (33.74%, 33.49%, and 32.76%) the total backlog values in the 3000+ and 2800-3000 brackets.
- Scenarios 1, 2, and 3 (low, medium, and high demand variation) influence equally (33.33%, 33.33%, and 33.33%) the total backlog values in the 3000+ and 2800-3000 brackets..
- Integration ratio X = 0.3 is the most frequent (34.14%) and heavily influences the total backlog values in the 3000+ and 2800-3000 brackets

When these results are compared to those of Table 8, we notice that combinations 6-11 and integration ratio X = 0.3 heavily influence both the most frequent response time values (the 8-9 and 7-8 brackets, Table 8) and the most frequent total backlog values (the 3000+ and 2800-3000 brackets, Table 13). This shows that there is a trade off between total response time and total backlog: the MTO-based portion of the supply chain allows the handling of the uncertainty present in such way that the total response time value can be reduced. However, the MTS-based portion of the supply chain causes the total backlog value increases because the level strategy (inventory-oriented) followed is not the most appropriate when uncertainty is present in the system.

5. Conclusions

The international supply chain (SC) is the way to compete in today's market. The business model used by the SC members must be dynamic in order to respond to changes in the customers' demands, at an appropriate cost. For this reason is that in practice, SC members have opted to use hybrid business models. The objective of this chapter was to quantitatively evaluate the influence these hybrid business models have on the performance of the supply chain. For this purpose, a systems dynamics (SD) simulation model was built and used to test a series of different scenarios (i.e. the effect of varying the level of demand uncertainty and lead time variation, and the effect of varying the business model integration ratio). Statistical data was collected regarding two performance criteria (i.e. total response time and total backlog). Some of the findings include:

- For high lead time uncertainty environments, MTO-oriented hybrid business models should be preferred by the supply chain partners (in order to obtain shorter response time values).
- For low demand uncertainty environments, MTS-oriented hybrid business models should be preferred by the supply chain partners (in order to obtain lower total backlog values).
- Allowing the supply chain partners to manage their operations on their own way - without imposing a specific business model – allows the achievement of the same total response time results.
- There is a trade off between total response time and total backlog. The MTO-based portion of the supply chain allows shorter response time values, while the MTS-based portion of the supply chain causes the total backlog values to increase.
- A proper combination of MTO-based and MTS-based SC partners allows the achievement of balanced results in both SC performance criteria.

As a conclusion we can say that the operation of the SC (as a whole) is greatly impacted by the individual configuration decisions (i.e. degree of hybrid business model used) of the SC partners, and that depending on the chosen SC performance criteria (i.e. total response time or total backlog), different arrangements should be preferred. This research effort acknowledges that several elements need to be incorporated into the SD simulation model in order to be considered a realistic one. For this reason, future research will address the balance between global (whole SC) and individual benefits (SC partners); the SC performance at the chain level and the operations level; the impact of varying the level of product standardization and process flexibility of each SC partner; the impact of demand distortion from SC partner to SC partner; and the impact of different lead time ratios among SC partners.

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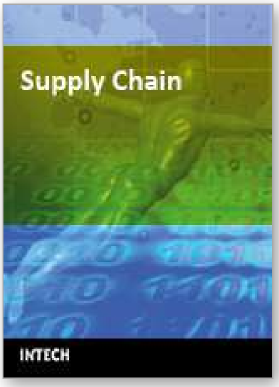

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