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Quantifying the Demand Fulfillment Capability of a Manufacturing Organization

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1. Introduction

According to [1], competition among manufacturing enterprises is fought between supply chains (SC). In this scenario, competitiveness becomes something holistic [2], as the satisfaction of the end customer is determined by the effectiveness and efficiency of the SC as a whole [3]. This goal of 'operating as a whole' is the result of the degree of interaction between the SC partners, which in turn depends on the type of business models used by them [4], i.e. engineer-to-order (ETO), make-to-order (MTO), assembly-to-order (ATO), make-to-stock (MTS), etc. According to [5] and [6], a poor SC performance can be attributed to a mismatch between the intended market and the business model used to address it. As the market changes from being sales-oriented to being market-oriented [7], an adequate response requires shifting between business models [8]. This last is not a trivial task in real-life as it requires each SC partner to realign their SC structural elements [9], from the strategic level of customer and supply issues to the operational level of process and equipment issues [10]. The reason behind this requirement is that decisions taken at the strategic level have a deep impact at the operational level [11], and the correct management of the operational level has a big impact on the efficiency of the strategic level [12], so even though strategic issues are important to achieve responsiveness to market changes, they are not sufficient without achieving responsiveness at the operational level [13].
In this paper we understand the strategic and operational levels of a manufacturing organization, in terms of the CPPR framework proposed by [14]: the strategic level of a manufacturing enterprise corresponds to the customer level of the CPPR framework, while the operational level corresponds to the process level of the CPPR framework.

1.1 Alignment relationships of the strategic - operational levels

According to the definition provided by [14], SC structural elements are the customer, product, process, and resource attributes of a manufacturing organization that allows its representation from a SC standpoint. Table 1 shows the set of SC structural elements and their configuration variables: a manufacturing organization is said to be 'aligned' when most of its configuration attributes fall under the same column (in this paper we use the term 'alignment' in the same sense). When these SC structural elements are analyzed from the standpoint of the 'what', 'when' and 'how much' of customer service [15], the following alignment relationships are found:

Table 1. SC structural elements and their configuration variables

BUSINESS	C Business model	MTO	MTO-ATO		ATO	
	C Company size	Very small (E<50)	Medium size (50<E<500)		Large size (E> 5	
	C Management style	Entrepreneurial				
	Pd Type	Machine tools	Motors		TV	
	Pc Environment	Job shop	Batch		Repetitiv	
	R Layout	Functional	Cellular		U-line	
SUPPLIER	C Logistics structure	Single plant/single warehouse	Multi plant/multi warehouses		Production/	
	C Procurement	Vertical production	Extensive outsourcing		Final assembly	
	Pc Delivery/total lead	1 – 4/5	4/5 – 2/5		2/5 – 1/	
	Pc Production/delivery	P/D<<1	P/D<1		P/D>1	
MANUFACTURING	Pd Composition	complex mfg.+assy.	simple mfg.+assy.		assy.	
	Pd Standardization	Customer's specs)	Own catalog, non-standard options		Standard wit	
	Pd Variety	many (100<n<1,000)	many –several (50<n<100)		several-few (5<	
	Pc Lead time	months-weeks	weeks-day		day-minu	
	Pc Volume	low (1-100 batch size)	low (100-1000 batch size)		medium -high (1,000-1	
	R Process flow	varied	varied with patterns		One-piec	
	R Technology	Universal	General purpose		General purpose-	
PLANNING	C Management focus	Capacity	Capacity, innovation		Innovatio	
	C Order promise	material/capacity availab.	Capacity, components stock availab.		Components stoc	
	CVariables fixed	Capacity, due date	Capacity, due date	Cost , due date	Cost, due date	
	Pc SFC approach	Push	Push	Push/Pull	Push/Pull	
	Pc PPC strategy	LOP	MRP		JIT	
	Pc Volume/mix manag.	Through order backing	Through order backing	WIP/FG inventory	Through WIP/F	
MARKETING	C Order winners/qualifiers	flexibility, innovation	flexibility, innovation, performance		performance, delive	
	PcOperations complexity	Component manufacturing				
	Pc Operations uncertainty	Production processes				
	R Labor requirements	High				
	R Materials requirements	As required/low				
CUSTOMER	C Demand uncertainty	Volatile				
	C Product destination	Known				
	Pd BOM	A type, V type	A type, V type, X type, T type,		X type, T type	
	Pc FG level	Low				
	Pc WIP level	High				
	R Direct labor costs	High				
	R Direct material costs	Low	High		High	

C = customer   Pd = product   Pc = process   R = resource

- The consumer's behavior (demand uncertainty) impacts the planning horizon of the market opportunity. In this way, demand uncertainty determines the level of customer feedback provided by the business model, i.e. as the demand becomes more unpredictable, no planning ahead of time can not take place and there is the need to wait for customer info.
- The business model establishes the Organization's approach to the identified market opportunity, understood in terms of order winners/qualifiers. In this way, the business model relies on the process environment, i.e. a make-to-stock (MTS) business model that requires having always ready-to-sell finished goods, must be supported by a mass production environment that produces high volumes of short-lead time products.
- The market opportunity is translated into a specific product. The capability of the Organization to manufacture different varieties of products depends in great deal on how much standardized the products' BOM structures are (as they allow the use of postponement and/or modularization approaches). In this way, product standardization allows the achievement of the order winners/qualifiers, i.e. the order winners/qualifiers delivery, cost, and quality are achievable when the product is of simple assembly.
- The process required to produce a product have time components that are greatly influenced by product's features (operations complexity, i.e. level of standardization) and process' capabilities (operations uncertainties, i.e. production volumes). In this way, the process environment is conditioned by the product standardization, i.e. a product with high levels of standardization (and simple to produce) allows high levels of production volumes.

It must be noted that there are four recurrent elements present in these alignment conditions: demand uncertainty, business model, product standardization, and process environment flexibility. In the next section we use these four elements to derive an analytical expression of the impact the strategic - operational levels alignment has on the performance of the manufacturing organization. Section 3 illustrates the usefulness of the analytical expression via the development of a simulation model, section 4 shows the sensitivity analysis performed over the proposed simulation model, and section 5 closes with the conclusions and future research.

2. Analytical expression of the demand fulfillment capability

According to [16] and [17], metrics used to measure the performance of the SC can be classified as strategic, tactical, and operational, where the performance of a SC partner can be expressed in terms such as customer satisfaction, product quality, speed in completing manufacturing orders, productivity, diversity of product line, flexibility in manufacturing new products, etc [18]. In this paper we use demand fulfillment - understood as the achievement of the demanded volume - as it relates to the four recurrent elements present in the alignment conditions of the previous section:

- Demand uncertainty (U); according to [19], when demand uncertainty is low, a make-to-stock (MTS) business model is recommended. When demand uncertainty is high, a make-to-order (MTO) business model is recommended.
- Business model (BM); according to [20], in a MTS business model production planning is made based on a forecast (rather than actual orders), allowing to produce ahead of time,

keep a stock, and ship upon receipt of orders. According to [21], when using this business model, an inventory-oriented level strategy should be used, where a steady production is maintained and finished goods inventory is used to absorb ongoing differences between output and sales. In the case of the case of the MTO business model, according to [20], production planning is made on actual orders (rather than on forecast), allowing to eliminate finished goods inventories. When using this business model, a capacity-oriented chase strategy should be used [21], where the expected demand is tracked and the corresponding capacity is computed, raising it or lowering it accordingly.

- Process environment flexibility (F); according to [19], when following a level strategy, a rigid continuous production line should be used. When following a chase strategy, a flexible job shop should be used.
- Product standardization (S); according to [22], a continuous production line uses special-purpose equipment - grouped around the product - to profitably manufacture high-volumes of standardized products. In the case of the of the job shop, it uses general-purpose equipment - grouped around the process – to profitably manufacture low-volumes of customized products.

As we can see in Figure 1, there is trade-off between the inventory-oriented and capacity-oriented strategies (or demand fulfillment strategies): the contribution increase/decrease of one implies the contribution decrease/increase of the other. This can be express in an analytical way:

- When uncertainty U is low (0), business model BM is MTS (0), standardization S is high (1), and flexibility F is low (0), demand is fulfilled 100% from inventory, Equation (1):

$$\text{Inventory contribution to demand fulfillment} = D * (1-U) * (1-BM) * S * (1-F) \qquad (1)$$

- When uncertainty U is high (1), business model BM is MTO (1), standardization S is low (0), and flexibility F is high (1), demand is fulfilled 100% from capacity, Equation (2):

$$\text{Capacity contribution to demand fulfillment} = D * U * BM *(1- S) * F \qquad (2)$$

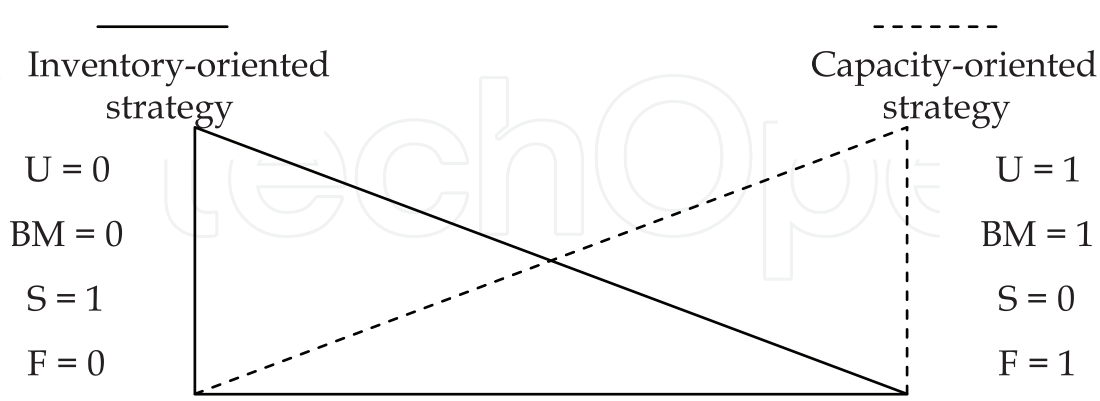


Fig. 1. Demand fulfillment relationships

In this way, demand fulfillment would be sum of the contributions made by the inventory-oriented and capacity-oriented strategies: for a totally aligned scenario (left or right sides of Figure 1), demand will be fulfilled by a 100% inventory-oriented or 100% capacity-oriented strategy; for a misaligned scenario, demand will be fulfilled by a combination of both strategies. Table 3 presents all the different combinations of limit conditions (that is, the 0's or 1's in Table 2), for a demand level of 100 units. As we can see, Equation (1) and (2) represent accurately the trade-off between the demand fulfillment strategies. Note: when the demand fulfillment equals to zero it means that even though some level of production takes place, the achieved demand volume is really low - when compared to the demanded volume - that it can be considered to be zero. For example, if demand equals to 100 units, there is high uncertainty in the demand (U = 1), the business model used is MTO (BM = 1), the product is totally standardized (S = 1), and it uses a functional job shop (F = 1). Here the high uncertainty of the demand requires waiting for customer feedback (provided by the MTO business model). However, the totally standardized product is characterized by using simple manufacturing and/or assembly operations (that take a really short time). In this case, the functional job shop used would affect the fulfillment of the 100 units, by presenting two obstacles to the flow of the process: 1) the set up times proper of the universal equipment used (very long compared to the production run), and 2) the moving time from one operation to the next (as all the equipment is grouped based on their functionality). In this way, the analytical expression of the alignment impact can not be taken as an estimator of the final values of the fulfilled demand, but instead, as an indicator of the capability of the manufacturing organization to achieve the demanded volume (or demand fulfillment capability indicator): the closer this indicator is to the demand volume, the more feasible it will be for the manufacturing organization to achieve the demanded volume.

Before proceeding to the next section, it must be noted that the customer service and the demand fulfillment relationships (presented in the previous sections), are well-known facts - by production managers and industrial engineers - that have been reported previously in the literature. What we consider to be an original contribution of this paper is taking these well-known facts of production engineering, and putting them in the form of the demand fulfillment capability indicator, an analytical expression that relates the degree of alignment (between the structural and operational levels) with demand fulfillment. Two similar demand fulfillment equations are presented in [23], but they only consider the uncertainty and business model configuration attributes. In our proposal, we extend that work by including the standardization and flexibility configuration attributes. Next section present the practical applications (and therefore its usefulness) of the derived analytical expression.

	0	**0.25**	**0.5**	**0.75**	**1**
Uncertainty	Low, std = 0% of demand	Low-medium, std = 7.5% of demand	Medium, std = 15% of demand	Medium-high, std = 22.5% of demand	High, std = 30% of demand
Business model	MTS	MTS-ATO	ATO	ATO-MTO	MTO
Standardization	Customer's specs	Own catalog, non-standard options	Own catalog, with standard options	Standard with options	Standard, no options
Flexibility	Mass assembly line	Repetitive U line	Batch U line	Batch cellular	Functional job shop

Table 2. Numeric values of the recurrent elements

	Demand fulfillment strategy															
				100% inventory- -oriented									100% Capacity- -oriented			
D	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
U	0	1	0	0	0	1	1	1	0	0	0	1	1	1	0	1
BM	0	0	1	0	0	1	0	0	1	1	0	1	1	0	1	1
S	0	0	0	1	0	0	1	0	1	0	1	1	0	1	1	1
F	0	0	0	0	1	0	0	1	0	1	1	0	1	1	1	1
Equation (1) result	0	0	0	**100**	0	0	0	0	0	0	0	0	**0**	0	0	0
Equation (2) result	0	0	0	**0**	0	0	0	0	0	0	0	0	**100**	0	0	0

Table 3. Results for different combinations of limit conditions

3. Practical application of the demand fulfillment capability indicator

Reference [24] presents the case of Company ABC, a furniture company experiencing unforeseen problems due to the implementation of company-wide policies that put into conflicts the alignment relationships (between the strategic and operational levels) mentioned in section 1.1. The impact these policies have on Company ABC's performance, can be evaluated by using Equation (1) and (2) and the following values (from Table 2):

- U = 0.25, for a somewhat predictable market demand.
- BM = 0.5, for having products stocked in a ready-to-assemble condition.
- S = 0.25, for the offered own catalog – no standards options.
- F = 0.75, for the use of manufacturing cells.

In this way, for a demand level of 100 units, the demand fulfillment feasibility indicator shows a total value of 9.37 (meaning that Company ABC has a really hard time trying to achieve the demanded volume of 100 units):

Inventory contribution	= 100 * (1-0.25) * (1-0.5) * 0.25 * (1-0.75)	=	2.34
Capacity contribution	= 100 * 0.25 * 0.5 *(1- 0.25) * 0.75……………	=	7.03
Total	=		9.37

At this point, Company ABC needs to explore the possibility of making some adjustments to their policies, by migrating from their current alignment conditions to new ones. This migration process implies either increasing or decreasing some of the business model, standardization, and/or flexibility values. Examples of such migration process can be found in [14]. The question becomes then which values to increase/decrease and in what amount. An alternative that Company ABC has to answer these questions is the development of a simulation model that guides its search for more advantageous alignment conditions. Some important business applications of simulation within SC scenarios are:

- A simulation model is generally accepted as a valuable aid for gaining insights into and making decisions about the manufacturing system [25].
- A simulation model provides a mean to evaluate the impact of policy changes and to answer 'what if?'and 'what's best?' questions [26].
- A simulation model is useful for performance prediction [27] and for representing time varying behaviors [28].
- A simulation model is maybe the only approach for analyzing the complex and comprehensive strategic level issues that need to consider the tactical and operational levels [29].

For this reason, and in order to show the practical use of our research contribution, Equations (1) and (2), in this paper we proceed in the following way:

- Develop of a simulation model of an automotive SC partner; following a similar approach to the one presented by [30], where a discrete event simulation model (of a SC) is implemented and an application example is proposed for a better understanding of the simulation model potential. The reason for choosing the case of an automotive SC partner obeys to the following reason: [31] presents a SC modeling methodology and uses the automotive SC in order to exemplify it. It must be noted that point 3 of the modeling methodology presented in [31] assumes that the demand fulfillment capability, of the partners within the automotive SC, depends only on the business model used. This is where we consider our research contribution can complement the modeling methodology presented in [31], by adding the uncertainty, standardization, and flexibility elements (Equations 1 and 2).
- Use of system dynamics (SD) as the simulation paradigm; following a similar approach to the one presented by [32], where a SD is employed to analyze the behavior and operation of a hybrid push/pull CONWIP-controlled lamp manufacturing SC. SD is one of the four simulation types mentioned by [33], and it is a system thinking approach that is not data driven, and that focuses on how the structure of a system and the taken policies affect its behavior [34]. According to [32], SD can be applied from macro perspective modeling (SC system) to micro perspective modeling (production floor system), and when applied to SC systems, it allows the analysis and decision on an aggregate level (which is more appropriate for supporting management decision-making, than conventional quantitative simulation).

Within this context, we use Equations (1) and (2) to develop an SD simulation model and use the situation of the automotive SC partner as an application example. In the case the simulation model is used as a decision making tool, then a Design of Experiment (DOE) or an Analysis of Variance (ANOVA) needs to be perform on the statistical analysis of the output, as the result of the decision making process depends on how experiments are planned and how experiments results are analyzed.

3.1 Simulation model of an automotive SC partner

Based on Equations (1) and (2), an SD simulation model was built using the simulation software [35]. The SD simulation model was verified and validated following a similar approach to the one in [36]: it was presented to experienced professionals in the area of simulation model building, and the simulation model output was examined for reasonableness under a variety of settings of input parameters. The SD simulation model developed for a partner of the automotive SC is presented in Figure 2. This model complies with the analytical model presented by [31]:

1. The SC has several independent partners.
2. There is no global coordinator to make decisions at all levels, decisions are made locally and decentralized.
3. The partners have only two kinds of inputs and outputs, material and information flows. Material and information flows are described using inventory level and order backlog equations.
4. Each partner operates as a pull system (driven by orders between the partners involved in the SC) that processes or satisfies orders only when it has a backlog or orders to be processed.

5. Each partner can handle one product family (i.e. wipers) or one a single product (i.e. a specific type of wiper). For SC of the automotive industry, modeling partners that are able only to handle one product represents a sufficient and realistic requirement.

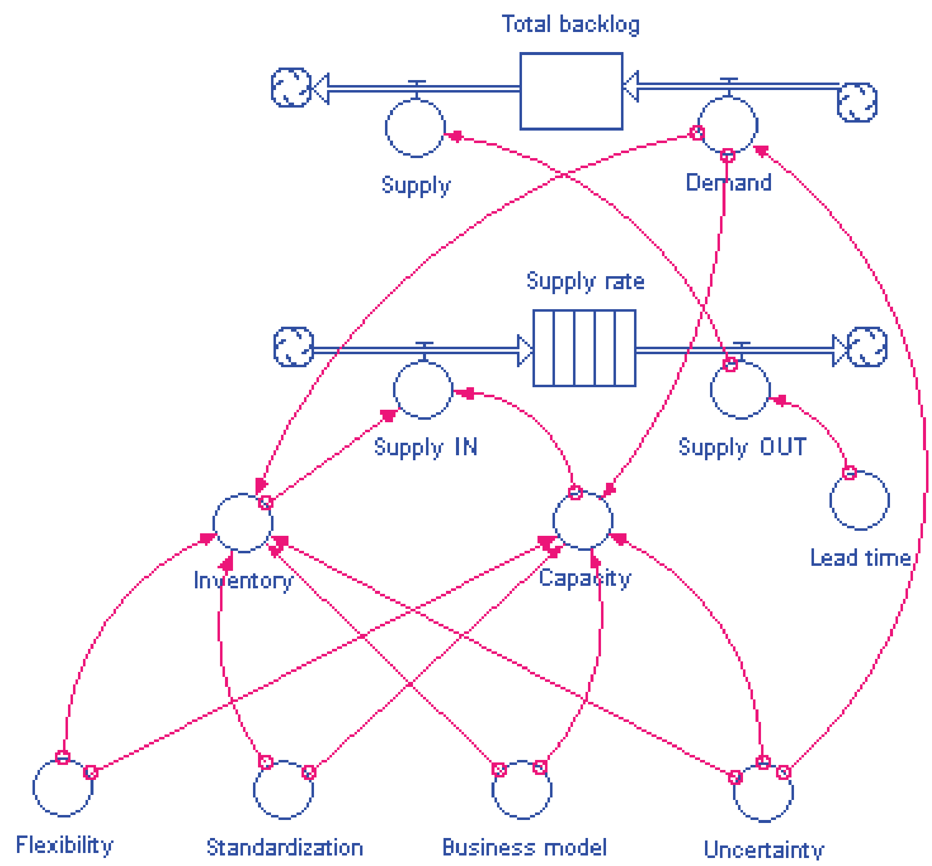


Fig. 2. SD simulation model of an automotive supply chain partner, as proposed by [31]

The performance criteria considered is demand fulfillment (in the form of the accumulated total backlog at the end of planning period T). The most important assumptions made in the simulation model are the following:

- *Total backlog* $_i$ is the difference between *Demand* $_i$ and *Supply* $_i$, during period *i* of the planning period T.
- *Demand* $_i$ varies according to a normal distribution, with a mean of 100 units and a standard deviation of *Uncertainty*. The normal distribution is used to represent a symmetrically variation above and below a mean value [37].
- *Uncertainty* ranges from 0 units (low) to 30 units (high).
- Supply $_i$ is equal to supply $_i$ OUT.
- *Supply* $_i$ *OUT* is equal to *Supply* $_i$ *IN* after a delay of *lead time* $_i$.
- *Lead time* $_i$ varies according to a uniform distribution and is given in weeks. The uniform distribution is used to represent the 'worst case' result of variances in the lead time [37].
- *Supply* $_i$ *IN* is the sum of the contribution made by *Inventory* $_i$ and *Capacity* $_i$. 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* ranges from 0 (MTS environment) to 1 (MTO environment).
- *Standardization* ranges from 0 (low) to high (1).
- *Flexibility* ranges from 0 (low) to high (1).

- *Inventory* $_i$ is equal to Equation (1):

  Demand * (1- Uncertainty) * (1- Business model) * Standardization * (1- Flexibility)
- *Capacity* P_i is equal to Equation (2):

  Demand * Uncertainty * Business model * (1- Standardization) * Flexibility

Figure 3 shows the analysis of a partner of the automotive supply chain. Stock elements were used to represent the *Backlog* P_i, due to its accumulating nature, while Conveyor elements were used to represent the delay of lead time units for fulfilling the order, due to its transit time feature.

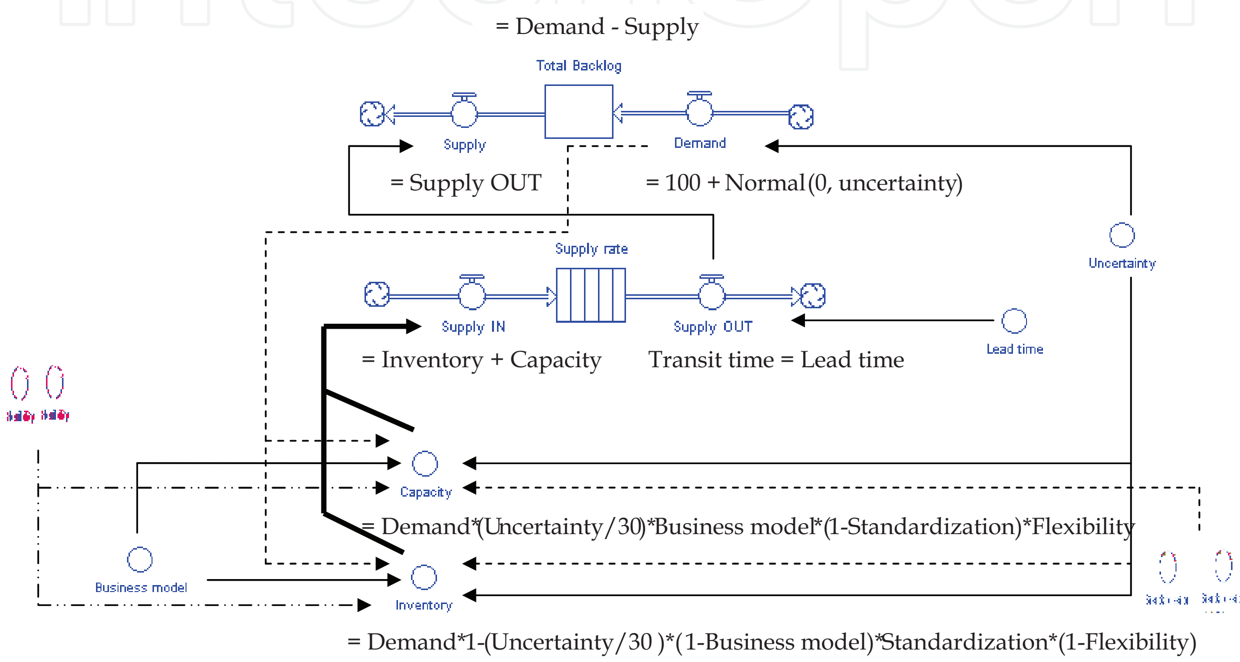


Fig. 3. Explanation of the elements of the SD simulation model

4. Sensitivity analysis

In order to study the effect of varying the level of demand uncertainty and lead time variation, 1875 different scenarios were tested:

- *Uncertainty* levels of 0, 7.5, 15, 22.5, and 30. As it was stated previously, these values represent the standard deviation (given in units) of the normal distribution used to represent the demand variation.
- *Business model*, *Standardization*, and *Flexibility* levels of 0, 0.25, 0.5, 0.75, and 1.
- *Lead time* levels of Uniform (1, 1), Uniform (1, 3), and Uniform (1, 5). In a uniform distribution, values spread uniformly between a minimum and a maximum value. In this way, Uniform (1,1) represent a low lead time variation (no variation), Uniform (1,3) represent medium lead time variation (values spread between 1 and 3 weeks), and Uniform (1,5) represent a high lead time variation (values spread between 1 and 5 weeks).

For a planning period T = 100 and thirty replications per scenario, confidence intervals of 95% level were constructed and reported in Tables 4, 5, and 6, which summarize the behavior of the total backlog values as standardization, flexibility, and business model increases from 0 to 1, uncertainty increases from 0 to 30, and lead time increases from low - Uniform (1, 1) - to high - Uniform (1, 5).

Table 4. Simulation output, low lead time variation

		u = 0					u = 7.5					u = 15					u = 22.5			
		s					s					s					s			
bm	f	0	0.25	0.5	0.75	1	0	0.25	0.5	0.75	1	0	0.25	0.5	0.75	1	0	0.25	0.5	0.7
0	0	10000	7525	5050	2575	100	9949.47	8142	6286.03	4429.3	2572.43	9949.5	8760.77	7523.13	6285.57	5047.6	9948.47	9379.5	8760.03	8140
	0.25	10000	8218	6337	4456	2575	9949.47	8605.9	7214	5821.7	4429.3	9949.5	9070.63	8141.53	7213.3	6285.57	9948.47	9533.97	9069.43	8605
	0.5	10000	8812	7525	6337	5050	9949.47	9070.7	8142	7214	6286.03	9949.5	9377.79	8760.77	8141.53	7523.13	9948.47	9688.57	9379.5	9069
	0.75	10000	9406	8812	8218	7525	9949.47	9537.23	9070.7	8605.9	8142	9949.5	9688.23	9379.77	9070.63	8760.77	9948.47	9845.07	9688.57	9533
	1	10000	10000	10000	10000	10000	9949.47	9949.47	9949.47	9949.47	9949.47	9949.5	9949.5	9949.5	9949.5	9949.5	9948.47	9948.47	9948.47	9948
0.25	0	10000	8218	6337	4456	2575	9949.47	8605.9	7214	5821.7	4429.3	9949.5	9070.63	8141.53	7213.3	6285.57	9948.47	9533.97	9069.43	8605
	0.25	10000	8614	7228	5842	4456	9850.47	8838.1	7833.47	6827.63	5821.7	9688.23	9070.63	8451.13	7831.87	7213.3	9533.97	9302.47	9069.43	8836
	0.5	10000	9109	8218	7228	6337	9681.83	9070.7	8452.37	7833.47	7214	9379.77	9070.63	8760.77	8451.13	8141.53	9069.43	9069.43	9069.43	9069
	0.75	10000	9604	9109	8614	8218	9537.23	9301.93	9070.7	8838.1	8605.9	9070.63	9070.63	9070.63	9070.63	9070.63	8605.67	8836.77	9069.43	9302
	1	10000	10000	10000	10000	10000	9379.4	9537.23	9681.83	9850.47	9949.47	8760.77	9070.63	9379.77	9688.23	9949.5	8140.87	8605.67	9069.43	9533
0.5	0	10000	8812	7525	6337	5050	9949.47	9070.7	8142	7214	6286.03	9949.5	9379.77	8760.77	8141.53	7523.13	9948.47	9688.57	9379.5	9069
	0.25	10000	9109	8218	7228	6337	9681.83	9070.7	8452.37	7833.47	7214	9379.77	9070.63	8760.77	8451.13	8141.53	9069.43	9069.43	9069.43	9069
	0.5	10000	9406	8812	8218	7525	9379.4	9070.7	8762.03	8452.37	8142	8760.77	8760.77	8760.77	8760.77	8760.77	8140.87	8450.33	8760.03	9069
	0.75	10000	9703	9406	9109	8812	9070.7	9070.7	9070.7	9070.7	9070.7	8141.53	8451.13	8760.77	9070.63	9379.77	7212.03	7826.4	8450.33	9069
	1	10000	10000	10000	10000	10000	8762.03	9070.7	9379.4	9681.83	9949.47	7523.13	8141.53	8760.77	9379.77	9949.5	6283.7	7212.03	8140.87	9069
0.75	0	10000	9406	8812	8218	7525	9949.47	9537.23	9070.7	8605.9	8142	9949.5	9688.23	9379.77	9070.63	8760.77	9948.47	9845.07	9688.57	9533
	0.25	10000	9604	9109	8614	8218	9537.23	9301.93	9070.7	8838.1	8605.9	9070.63	9070.63	9070.63	9070.63	9070.63	8605.67	8836.77	9069.43	9302
	0.5	10000	9703	9406	9109	8812	9070.7	9070.7	9070.7	9070.7	9070.7	8141.53	8451.13	8760.77	9070.63	9379.77	7212.03	7832.3	8450.33	9069
	0.75	10000	9901	9703	9604	9406	8605.9	8838.1	9070.7	9301.93	9537.23	7213.3	7831.87	8451.13	9070.63	9688.23	5280.03	6825.23	7832.3	8836
	1	10000	10000	10000	10000	10000	8142	8605.9	9070.7	9537.23	9949.47	6285.57	7213.3	8141.53	9007.63	9949.5	4426.9	5820.03	7212.03	8605
1	0	10000	10000	10000	10000	10000	9949.47	9949.47	9949.47	9949.47	9949.47	9949.5	9949.5	9949.5	9949.5	9949.5	9948.47	9948.47	9948.47	9948
	0.25	10000	10000	10000	10000	10000	9379.4	9537.23	9681.83	9850.47	9949.47	8760.77	9070.63	9379.77	9688.23	9949.5	8140.87	8605.67	9069.43	9533
	0.5	10000	10000	10000	10000	10000	8762.03	9070.7	9379.4	9681.83	9949.47	7523.13	8141.53	8760.77	9379.77	9949.5	6283.7	7212.03	8410.87	9069
	0.75	10000	10000	10000	10000	10000	8142	8605.9	9070.7	9537.23	9949.47	6285.57	7213.3	8141.53	9070.63	9949.5	4426.9	5820.03	7212.03	8605
	1	10000	10000	10000	10000	10000	7523.83	8142	8762.03	9379.4	9949.47	5047.6	6283.57	7523.13	8760.77	9949.5	2568.77	4426.9	6283.7	8140

Table 5. Simulation output, medium lead time variation

		u = 0					u = 7.5					u = 15					u = 22.5		
		s					s					s					s		
bm	f	0	0.25	0.5	0.75	1	0	0.25	0.5	0.75	1	0	0.25	0.5	0.75	1	0	0.25	0.5
0	0	10000	7560.83	5121.67	2682.5	243.33	9949.47	8167.73	6338.07	4507.9	2677.33	9949.5	8777.4	7557.1	6336.83	5116.27	9948.47	9387.17	8776.23
	0.25	10000	8243.8	6390.03	4536.27	2682.5	9949.47	8625.1	7253	5880.4	4507.9	9949.5	9083	8166.87	7251.63	6336.83	9948.47	9539.53	9081.37
	0.5	10000	8829.2	7560.83	6390.03	5121.67	9949.47	9083.23	8167.73	7253	6338.07	9949.5	9387.7	8777.4	8166.87	7557.1	9948.47	9691.93	9387.17
	0.75	10000	9414.6	8829.2	8243.8	7560.83	9949.47	9543.17	9083.23	8625.1	8167.73	9949.5	9691.87	9387.7	9083	8777.4	9948.47	9846.37	9691.93
	1	10000	10000	10000	10000	10000	9949.47	9949.47	9949.47	9949.47	9949.47	9949.5	9949.5	9949.5	9949.5	9949.5	9948.47	9948.47	9948.47
0.25	0	10000	8243.8	6390.03	4536.27	2682.5	9949.47	8625.1	7253	5880.4	4507.9	9949.5	9083	8166.87	7251.63	6336.83	9948.47	9539.53	9081.37
	0.25	10000	8634.07	7268.13	5902.2	4536.27	9851.9	8853.97	7863.63	6871.97	5880.4	9691.87	9083	8472.1	7861.5	7251.63	9539.53	9311.3	9081.37
	0.5	10000	9121.9	8243.8	7268.13	6390.03	9685.57	9083.23	8473.6	7863.63	7253	9387.7	9083	8777.4	8472.1	8166.87	9081.37	9081.37	9081.37
	0.75	10000	9609.73	9121.9	8634.07	8243.8	9543.17	9311.17	9083.23	8853.97	8625.1	9083	9083	9083	9083	9083	8624.17	8852.13	9081.37
	1	10000	10000	10000	10000	10000	9387.47	9543.17	9685.57	9851.9	9949.47	8777.4	9083	9387.7	9691.87	9949.5	8165.57	8624.17	9081.37
0.5	0	10000	8829.2	7560.83	6390.03	5121.67	9949.47	9083.23	8167.73	7253	6338.07	9949.5	9387.7	8777.4	8166.87	7557.1	9948.47	9691.93	9387.17
	0.25	10000	9121.9	8243.8	7268.13	6390.03	9685.57	9083.23	8473.6	7863.63	7253	9387.7	9083	8777.4	8472.1	8166.87	9081.37	9081.37	9081.37
	0.5	10000	9414.6	8829.2	8243.8	7560.83	9387.47	9083.23	8778.9	8473.6	8167.73	8777.4	8777.4	8777.4	8777.4	8777.4	8165.57	8470.87	8776.23
	0.75	10000	9707.3	9414.6	9121.9	8829.2	9083.23	9083.23	9083.23	9083.23	9083.23	8166.87	8472.1	8777.4	9083	9387.7	7249.67	7861.33	8470.87
	1	10000	10000	10000	10000	10000	8778.9	9083.23	9387.47	9685.57	9949.47	7557.1	8166.87	8777.4	9387.7	9949.5	6333.97	7249.67	8165.57
0.75	0	10000	9414.6	8829.2	8243.8	7560.83	9949.47	9543.17	9083.23	8625.1	8167.73	9949.5	9691.87	9387.7	9083	8777.4	9948.47	9846.37	9691.93
	0.25	10000	9609.73	9121.9	8634.07	8243.8	9543.17	9311.17	9083.23	8853.97	8625.1	9083	9083	9083	9083	9083	8624.17	8852.13	9081.37
	0.5	10000	9707.3	9414.6	9121.9	8829.2	9083.23	9083.23	9083.23	9083.23	9083.23	8166.87	8472.1	8777.4	9083	9387.7	7249.67	7861.33	8470.87
	0.75	10000	9902.43	9707.3	9609.73	9414.6	8625.1	8853.97	9083.23	9311.17	9543.17	7251.63	7861.5	8472.1	9083	9691.87	5876.73	6868.03	7861.33
	1	10000	10000	10000	10000	10000	8167.73	8625.1	9083.23	9543.17	9949.47	6336.83	7251.63	8166.87	9083	9949.5	4502.77	5876.73	7249.67
1	0	10000	10000	10000	10000	10000	9949.47	9949.47	9949.47	9949.47	9949.47	9949.5	9949.5	9949.5	9949.5	9949.5	9948.47	9948.47	9948.47
	0.25	10000	10000	10000	10000	10000	9387.47	9543.17	9685.57	9851.9	9949.47	8777.4	9083	9387.87	9691.87	9949.5	8165.57	8624.17	9081.37
	0.5	10000	10000	10000	10000	10000	8778.9	9083.23	9387.47	9685.57	9949.47	7557.1	8166.87	8777.4	9387.7	9949.5	6333.97	7249.67	8165.57
	0.75	10000	10000	10000	10000	10000	8167.73	8625.1	9083.23	9543.17	9949.47	6336.83	7251.63	8166.87	9083	9949.5	4502.77	5876.73	7249.67
	1	10000	10000	10000	10000	10000	7558.37	8167.73	8778.9	9387.47	9949.47	5116.27	6336.83	7557.1	8777.4	9949.5	2670.17	4502.77	6333.97

Table 6. Simulation output, high lead time variation

		u = 0					u = 7.5					u = 15					u = 2		
		s					s					s					s		
bm	f	0	0.25	0.5	0.75	1	0	0.25	0.5	0.75	1	0	0.25	0.5	0.75	1	0	0.25	0.5
0	0	10000.00	7587.50	5175.00	2762.50	350.00	9949.47	8187.00	6377.30	4567.03	2756.30	9949.50	8790.13	7583.03	6375.87	5168.50	9948.47	9393.27	8788
	0.25	10000.00	8263.00	6429.50	4596.00	2762.50	9949.47	8639.47	7282.30	5924.60	4567.03	9949.50	9092.40	8186.13	7280.77	6375.87	9948.47	9543.87	9090
	0.5	10000.00	8842.00	7587.50	6429.50	5175.00	9949.47	9092.67	8187.00	7282.30	6377.30	9949.50	9393.83	8790.13	8186.13	7583.03	9948.47	9694.67	9393
	0.75	10000.00	9421.00	8842.00	8263.00	7587.50	9949.47	9547.53	9092.67	8639.47	8187.00	9949.50	9694.67	9393.83	9092.40	8790.13	9948.47	9847.47	9694
	1	10000.00	10000.00	10000.00	10000.00	10000.00	9949.47	9949.47	9949.47	9949.47	9949.47	9949.50	9949.50	9949.50	9949.50	9949.50	9948.47	9948.47	9948
0.25	0	10000.00	8263.00	6429.50	4596.00	2762.50	9949.47	8639.47	7282.30	5924.60	4567.03	9949.50	9092.40	8186.13	7280.77	6375.87	9948.47	9543.87	9090
	0.25	10000.00	8649.00	7298.00	5947.00	4596.00	9852.97	8865.83	7886.30	6905.47	5924.60	9694.67	9092.40	8488.03	7884.10	7280.77	9543.87	9318.17	9090
	0.5	10000.00	9131.50	8263.00	7298.00	6429.50	9688.47	9092.67	8489.60	7886.30	7282.30	9393.83	9092.40	8790.13	8488.03	8186.13	9090.63	9090.63	9090
	0.75	10000.00	9614.00	9131.50	8649.00	8263.00	9547.53	9318.07	9092.67	8865.83	8639.47	9092.40	9092.40	9092.40	9092.40	9092.40	8638.40	8863.93	9090
	1	10000.00	10000.00	10000.00	10000.00	10000.00	9393.60	9547.53	9688.47	9852.97	9949.47	8790.13	9092.40	9393.83	9694.67	9949.50	8184.67	8638.40	9090
0.5	0	10000.00	8842.00	7587.50	6429.50	5175.00	9949.47	9092.67	8187.00	7282.30	6377.30	9949.50	9393.83	8790.13	8186.13	7583.03	9948.47	9694.67	9393
	0.25	10000.00	9131.50	8263.00	7298.00	6429.50	9688.47	9092.67	8489.60	7886.30	7282.30	9393.83	9092.40	8790.13	8488.03	8186.13	9090.63	9090.63	9090
	0.5	10000.00	9421.00	8842.00	8263.00	7587.50	9393.60	9092.67	8791.70	8489.60	8187.00	8790.13	8790.13	8790.13	8790.13	8790.13	8184.67	8486.63	8788
	0.75	10000.00	9710.50	9421.00	9131.50	8842.00	9092.67	9092.67	9092.67	9092.67	9092.67	8186.13	8488.03	8790.13	9092.40	9393.83	7278.67	7883.77	8486
	1	10000.00	10000.00	10000.00	10000.00	10000.00	8791.70	9092.67	9393.60	9688.47	9949.47	7583.03	8186.13	8790.13	9393.83	9949.50	6372.73	7278.67	8184
0.75	0	10000.00	9421.00	8842.00	8263.00	7587.50	9949.47	9547.53	9092.67	8639.47	8187.00	9949.50	9694.67	9393.83	9092.40	8790.13	9948.47	9847.47	9694
	0.25	10000.00	9614.00	9131.50	8649.00	8263.00	9547.53	9318.07	9092.67	8865.83	8639.47	9092.40	9092.40	9092.40	9092.40	9092.40	8638.40	8863.93	9090
	0.5	10000.00	9710.50	9421.00	9131.50	8842.00	9092.67	9092.67	9092.67	9092.67	9092.67	8186.13	8488.03	8790.13	9092.40	9393.83	7278.67	7883.77	8486
	0.75	10000.00	9903.50	9710.50	9614.00	9421.00	8639.47	8865.83	9092.67	9318.07	9547.53	7280.77	7884.10	8488.03	9092.40	9694.67	5920.43	6901.13	7883
	1	10000.00	10000.00	10000.00	10000.00	10000.00	8187.00	8639.47	9092.67	9547.53	9949.47	6375.87	7280.77	8186.13	9092.40	9949.50	4561.20	5920.43	7278
1	0	10000.00	10000.00	10000.00	10000.00	10000.00	9949.47	9949.47	9949.47	9949.47	9949.47	9949.50	9949.50	9949.50	9949.50	9949.50	9948.47	9948.47	9948
	0.25	10000.00	10000.00	10000.00	10000.00	10000.00	9393.60	9547.53	9688.47	9852.97	9949.47	8790.13	9092.40	9393.83	9694.67	9949.50	8184.67	8638.40	9090
	0.5	10000.00	10000.00	10000.00	10000.00	10000.00	8791.70	9092.67	9393.60	9688.47	9949.47	7583.03	8186.13	8790.13	9393.83	9949.50	6372.73	7278.67	8184
	0.75	10000.00	10000.00	10000.00	10000.00	10000.00	8187.00	8639.47	9092.67	9547.53	9949.47	6375.87	7280.77	8186.13	9092.40	9949.50	4561.20	5920.43	7278
	1	10000.00	10000.00	10000.00	10000.00	10000.00	7584.37	8187.00	8791.70	9393.60	9949.47	5168.50	6375.87	7583.03	8790.13	9949.50	2748.30	4561.20	6372

4.1 Standardization increase

When using the scenarios with a standardization level of zero as a comparison basis, an analysis of Tables 4, 5, and 6 reveals the same behavior:

- Below the diagonal that goes from BM = 1, U = 0 to BM = 0, U = 1 (Figure 4), the total backlog values decrease 76% of the time, remains the same 18% of the time, and increase 6% of the time. These results are explained by the fact that the U, BM and S values tend to the alignment conditions of a 100% inventory-oriented demand fulfillment strategy (U = 0, BM = 0, S = 1).
- Within the diagonal, the total backlog values decrease 24% of the time, remains the same 52% of the time, and increase 24% of the time.
- Above the diagonal, the total backlog values decrease 6% of the time, remains the same 18% of the time, and increase 76% of the time. These results are explained by the fact that the U and BM values tend to the alignment conditions of a 100% capacity-oriented demand fulfillment strategy (U = 1, BM = 1), but the S values are moving away (S = 0).

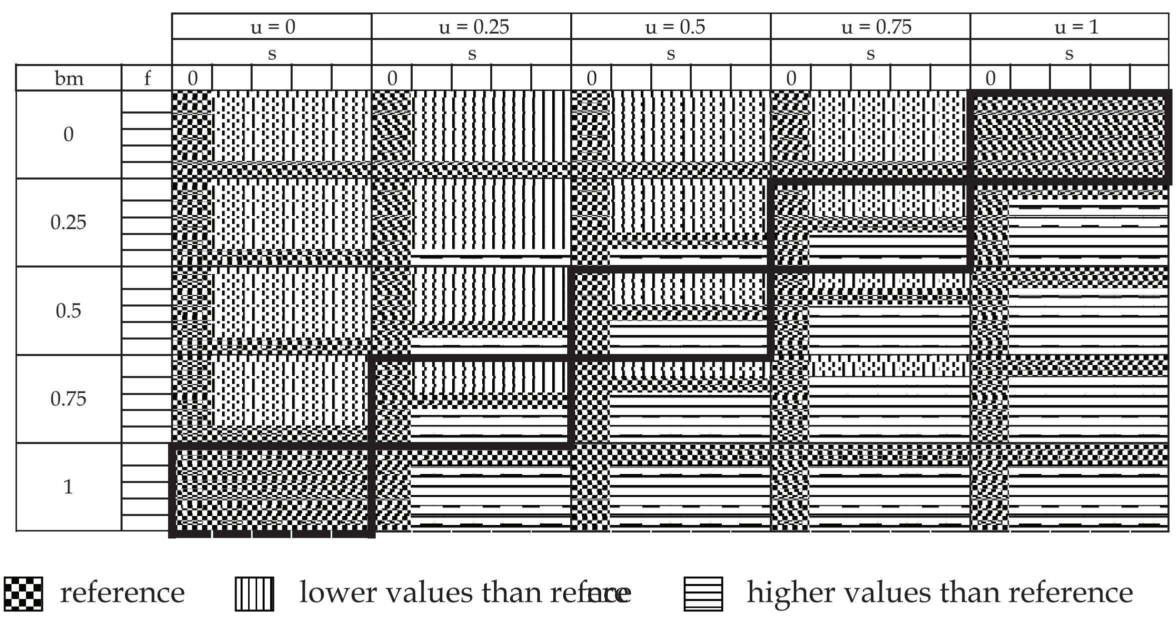


Fig. 4. Standardization increase

4.2 Flexibility increase

When using the scenarios with a flexibility level of zero as a comparison basis, an analysis of Tables 4, 5, and 6 reveals the same behavior:

- Below the diagonal, the total backlog values decrease 76% of the time, remains the same 18% of the time, and increase 6% of the time. These results are explained by the fact that the U, BM, and F values tend to the alignment conditions of a 100% capacity-oriented demand fulfillment strategy (U = 1, BM = 1, F = 1).
- Within the diagonal, the total backlog values decrease 24% of the time, remains the same 52% of the time, and increase 24% of the time.
- Above the diagonal that goes from BM = 1, U = 0 to BM = 0, U = 1 (Figure 5), the total backlog values decrease 6% of the time, remains the same 18% of the time, and increase 76% of the time. These results are explained by the fact that the U and BM values tend to the alignment conditions of a 100% inventory-oriented demand fulfillment strategy (U = 0, BM = 0), but the F values are moving away (F = 0).

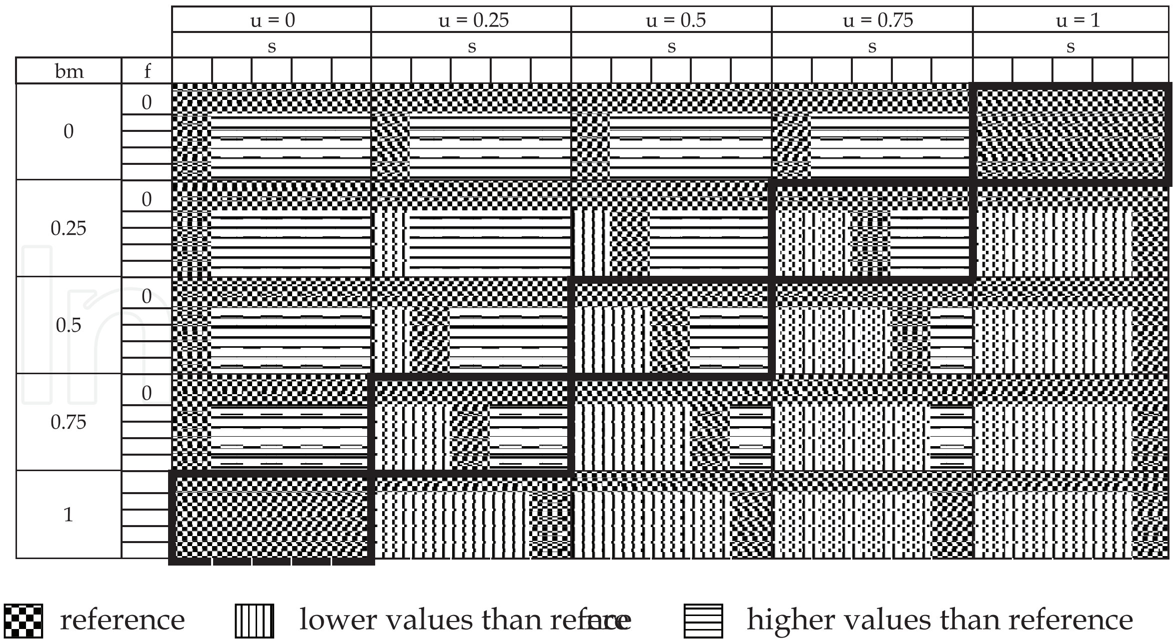


Fig. 5. Flexibility increase

4.3 Uncertainty and business model increase

When using (as a comparison basis) the total backlog values of the scenarios with uncertainty and business model equal to 0, we found that higher (or equal) total backlog values are found more frequently than lower values when there is a mismatch between the level of demand uncertainty present and the business model used to cope with it (lower left quadrant and upper right quadrant of Figure 6). An interesting fact is the role played by uncertainty in this mismatch: when uncertainty is low, 100% of the time higher (or equal) total backlog values are found (lower left quadrant of Figure 6). But when uncertainty is total then lower total backlog values can be found (lower right quadrant of Figure 6). This suggests that as the level of uncertainty increases, lower total backlog values are to be found (independently of the level of business model used).

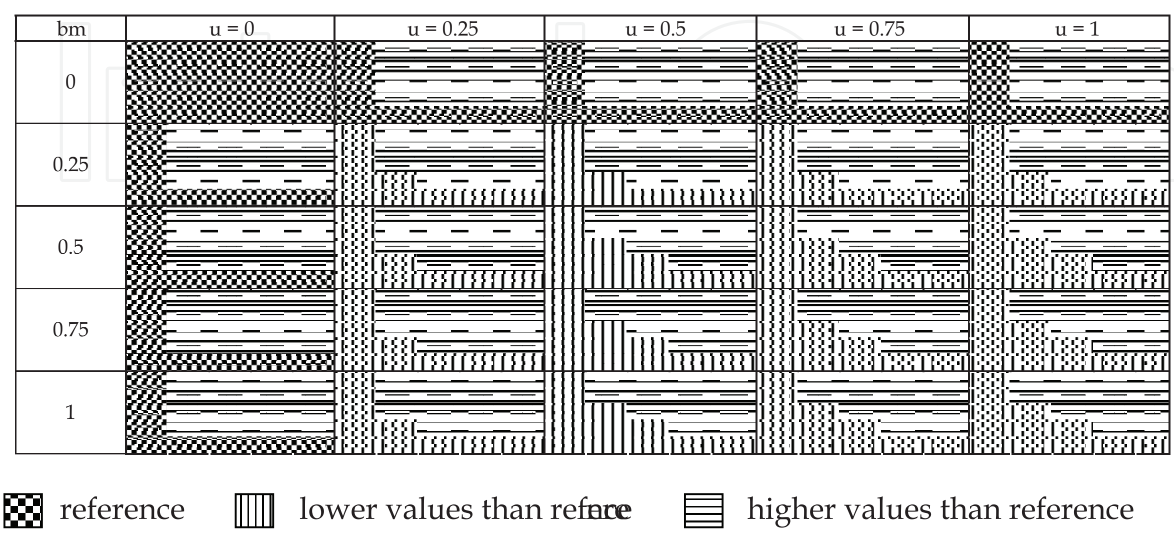


Fig. 6. Comparison of scenarios, uncertainty and business model values increase

In fact, when using the scenarios with a business model level of zero as a comparison basis, an analysis of Tables 4, 5, and 6 reveals the same behavior: within the same level of uncertainty, all the different business model levels (i.e. bm = 0, 0.25, 0.5, etc.), present the same the total backlog values behavior. In this way, for an uncertainty level of:

- 0; total backlog values decrease 0% of the time, remain the same 36% of the time, and increase 64% of the time.
- 0.25; total backlog values decrease 32% of the time, remain the same 16% of the time, and increase 52% of the time.
- 0.5; total backlog values decrease 40% of the time, remain the same 20% of the time, and increase 40% of the time.
- 0.75; total backlog values decrease 52% of the time, remain the same 16% of the time, and increase 32% of the time.
- 1.0; total backlog values decrease 64% of the time, remain the same 36% of the time, and increase 0% of the time.

4.4 Total backlog values frequency

When the values of Tables 4, 5, and 6 are classified according to the frequency a value appears within certain range, we found that:

- The distribution of the values is symmetrical (for the most part). This behavior has to do with the assumption that there is a continuum betwen the contributions made to demand fulfillment, by the inventory and the capacity strategies, Equations (1) and (2).

Total backlog values can be obtained through different combinations of u, bm, s, and f (Table 7), i.e. eight total backlog values in the range of 2,000 – 3,000.

Value range	frequency	frequency %
10000+	62	9.76
9000-10000	314	50.4
8000-9000	134	21.6
7000-8000	52	8.32
6000-7000	26	4.16
5000-6000	16	2.56
4000-5000	12	1.76
2000-3000	8	1.28
0-1000	2	0.16

Table 7. Total backlog values frequency

4.5 Implications for the automotive SC partner

As the level of uncertainty can not be controlled by the automotive SC partner, this last has to focus in adjusting the levels of standardization and/or flexibility rather than in adjusting the level of business model: while a total match between the business model used an the level of uncertainty present is not a guarantee of 100% lower total backlog values, neither a total mismatch guarantee 100% higher total backlog values. In fact, [38] reports that the standardization of a small number of semi-finished products resulted in a large reduction in the average lead times and with this, the increasing of volume of customer orders that can be processed during a certain period of volatile demand. If we take into account that a business

model can be understood in terms of its level of customer feedback [23], i.e. all the activities in a pure MTO environment are driven by customer's information (so uncertainty of what to do next, when to do it, and for how long to do it, is at its maximum), then further research is called in the area of optimum customer feedback **(**that is, the level of customer feedback information with the least cost that allows the maximum reduction of the total backlog value**)**.
A second implication is related to the frequency of the total backlog values: the automotive SC partner should follow and adaptive strategy in the management of its operations, as the same total backlog values can be obtained through different combinations of uncertainty, business model, standardization, and flexibility. Therefore, it is necessary to not only determine the optimum level customer feedback (as proposed earlier), but also the range of matchness (between uncertainty and the business model used) that would allow achieving a high frecuency of lower total backlog values, in the event of dealing with a high varying environment.

5. Conclusions

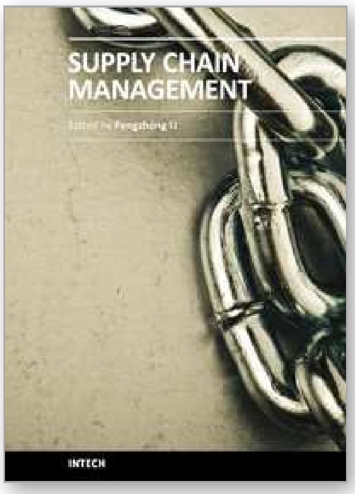
Manufacturing enterprises are pressured to shift from the traditional MTS to the MTO production model, and at the same time, compete against each other as part of a SC, in order to respond to changes in the customers' demands. As the decisions taken at the strategic level of the SC have a deep impact at the operational level of the manufacturing organization, it becomes necessary the alignment of activities, from the strategic level through the operational level. The objective of this paper was to quantitatively evaluate the impact of such alignment of the total backlog value of a manufacturing organization. For this reason, an analytical expression was derived a system dynamics (SD) simulation model was developed and tested under different scenarios (in order to collect statistical data regarding total backlog). The usefulness of the analytical expression was illustrated via a case study of an automotive SC partner and conclusions were derived regarding actions to improve its demand fulfillment capability. This research effort acknowledges that the misalignment between the strategic and operational levels creates an obstacle to demand fulfillment: the bigger the misalignment is, the bigger the obstacle to achieve the demanded volume will be. This idea resembles the concept of structural complexity proposed by [39], whom states that a high level of complexity in the structure of a production system (i.e. the number of operations and machines present in the routing sheets of a product family), has the effect of building obstacles that impedes the process flow. Future research will explore this venue and also, the use of a simulation-by-optimization approach (that is, finding out values of the decision variables which optimize a quantitative objective function under constraints).

6. References

[1] Ismail, H.S., Sharifi, H., A balanced approach to building agile supply chains, International Journal of Physical Distribution & Logistics Management 36 (6) (2006) 431-444.
[2] Duclos, L., Vokurka, R., Lummus, R. A conceptual model of supply chain flexibility, Industrial Management & Data Systems 103 (6) (2000) 446-456.
[3] Terzi, S., Cavalieri, S. Simulation in the supply chain context: a survey, Computers in Industry 53 (2004) 3–16.
[4] Ngai, E.W.T., Gunasekaran, A. Build-to-order supply chain management: a literature review and framework for development, Journal of Operations Management 23 (2005) 423–451.

[5] Li, D., O'Brien, C. 1999. Integrated decision modeling of supply chain efficiency, International Journal of Production Economics 59 (1999) 147-157.
[6] Li, D., O'Brien, C. A quantitative analysis of relationships between product types and supply chain strategies, International Journal of Production Economics 73 (2001) 29-39.
[7] Vonderembse, M.A., Uppal, M., Huang, S.H., Dismukes, J.P. Designing supply chains: Towards theory development, International Journal of Production Economics 100 (006) 223–238.
[8] Olhager, J. Strategic positioning of the order penetration point, International Journal of Production Economics 85 (3) (2003) 2335-2351.
[9] Vernadat, F. UEML: towards a unified enterprise modeling language, International Journal of Production Research 40 (17) (2002) 4309-4321.
[10] Angelides, M.C., Angerhofer, B.J. A model and a performance measurement system for collaborative supply chains, Decision Support Systems 42 (2006) 283– 301.
[11] Son, Y.J., Venkateswaran, J. Hybrid system dynamic: discrete event simulation-based architecture for hierarchical production planning, International Journal of Production Research 43 (20) (2005) 4397–4429.
[12] Khoo, L.P., Yin, X.F. An extended graph-based virtual clustering-enhanced approach to supply chain optimization, International Journal of Advanced Manufacturing Technology 22 (2003) 836–847.
[13] Zhang, D.Z., Anosike, A.I., Lim, M.K., Akanle,O.M. An agent-based approach for e-manufacturing and supply chain integration, Computers & Industrial Engineering 51 (2006) 343–360.
[14] Martinez-Olvera, C., Shunk, D. A comprehensive framework for the development of a supply chain strategy, International Journal of Production Research 44 (21) (2006) 4511–4528.
[15] Griffiths, J., James, R., Kempson, J. Focusing customer demand through manufacturing supply chains by the use of customer focused cells: an appraisal. International Journal of Production Economics 65 (1) (2000) 111-120.
[16] Chibba, A., Ake Horte, S., Supply chain performance – A Meta Analysis, European operations management association & Production and operations management society, Joint conference, June, 16-18 (2003).
[17] Gunasekaran, A., Patelb, C., McGaughey, R.E. A framework for supply chain performance measurement, International Journal of Production Economics 87 (2004) 333–347.
[18] Chen, C., C. An objective-oriented and product-line-based manufacturing performance measurement, International Journal of Production Economics 112 (2008) 380–390.
[19] Safizadeh, M.H., Ritzman, L.P. Linking performance drivers in production planning and inventory control to process choice, Journal of Operations Management 15 (1997) 389-403
[20] Gupta, D., Benjaafar, S. Make-to-order, make-to-stock, or delay product differentiation? A common framework for modeling and analysis, IIE Transactions 36 (2004) 529–546.
[21] Buxey, G. Strategy not tactics drives aggregate planning, International Journal of Production Economics 85 (2003) 331–346.
[22] Miltenburg, J. Manufacturing Strategy: How to Formulate and Implement a Winning Plan, Productivity Press, Portland, Oregon (1995).

[23] Martinez-Olvera, C. Impact of hybrid business models in the supply chain performance, book chapter. Supply Chain: Theory and Applications, ISBN 978-3-902613-22-6. I-Tech Education and Publishing, Vienna, Austria, European Union (2008a).
[24] Martinez-Olvera, C. Methodology for realignment of supply-chain structural, International Journal of Production Economics, doi:10.1016/j.ijpe.2008.03.008 (2008b),
[25] Huang, S.H., Uppal, M., Shi, J. A product driven approach to manufacturing supply chain selection, Supply chain management 7 (4) (2002) 189-199.
[26] Shah, N., Hung, W.Y., Kucherenko, S., Samsatli, N.J. A flexible and generic approach to dynamic modelling of supply chains, Journal of the Operational Research Society 55 (2004) 801–813.
[27] Towill, D.R. Time compression and supply chain management – a guided tour. Supply chain management 1 (1) (1996) 15-27.
[28] Venkateswaran, J., Son, Y. J. Impact of modeling approximations in supply chain analysis – an experimental study, International Journal of Production Research 42 (15) (2004) 2971–2992.
[29] Zhao, Z.Y., Ball, M., Chen, C.Y. A scalable supply chain infrastructure research test-bed. Department of decision & information technology. Robert H. Smith, School of Business, University of Maryland (2002).
[30] Longo, F., Mirabelli, G. An advanced supply chain management tool based on modeling and simulation, Computers & Industrial Engineering 54 (2008) 570–588.
[31] Roder, A., Tibken, B. A methodology for modeling inter-company supply chains and for evaluating a method of integrated product and process documentation, European Journal of Operational Research 169 (2006) 1010–1029.
[32] Huang, M., Ip, W.H., Yung, K.L., Wang, X., Wang, D. Simulation study using system dynamics for a CONWIP-controlled lamp supply chain, International Journal of Advanced Manufacturing Technology 32 (2007) 184–193. DOI 10.1007/s00170-005-0324-2
[33] Kleijnen, J.P.C. Supply chain simulation tools and techniques: a survey, International Journal of Simulation & Process Modelling 1 (1/2) (2005) 82-89.
[34] Eskandari, H., Rabelo, L., Shaalan, T., Helal, M. Value chain analysis using hybrid simulation and AHP, International Journal of Production Economics 105 (2007) 536–547.
[35] iThink Analyst Technical Documentation, High Performance Systems, Inc. (1996)
[36] Hwarng, H. B., Chong, C. S. P., Xie, N., Burgess, T.F., 2005. Modeling a complex supply chain: understanding the effect of simplified assumptions, International Journal of Production Research 43 (13) (2005) 2829–2872.
[37] Banks, J. Discrete-event system simulation, Upper Saddle River, NJ : Prentice Hall. (2000)
[38] Kuroda, M., Mihira, H. Strategic inventory holding to allow the estimation of earlier due dates in make-to-order production, International Journal of Production Research 46 (2) (2008) 495–508.
[39] Frizelle, G., Woodcock, E. Measuring complexity as an aid to developing strategy, International Journal of Operations & Production Management 15 (5) (1995) 268-270.



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The purpose of supply chain management is to make production system manage production process, improve customer satisfaction and reduce total work cost. With indubitable significance, supply chain management attracts extensive attention from businesses and academic scholars. Many important research findings and results had been achieved. Research work of supply chain management involves all activities and processes including planning, coordination, operation, control and optimization of the whole supply chain system. This book presents a collection of recent contributions of new methods and innovative ideas from the worldwide researchers. It is aimed at providing a helpful reference of new ideas, original results and practical experiences regarding this highly up-to-date field for researchers, scientists, engineers and students interested in supply chain management.