28 A COMPARISON OF SUPPLY CHAIN MANAGEMENT POLICIES

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Supply chain management practices and principles evolve rapidly, driven by information and communication technology innovations. These innovations impel the supply chain design and management. Constantly new management strategy and operations practices appear and need to be evaluated before their actual introduction in the system. This paper presents a comparison of three supply chain management policies considering distributed and centralized decision processes through discrete time simulation and shows how the visibility of information interfere in the supply chain performance

1. INTRODUCTION

Supply Chain (SC) is a system composed of connected organizations (suppliers, original equipment manufacturers, distributors, transporters), involved in the creation and delivery of value, in the form of both finished products and services to end customers (Pant, 2003). The relationship among partners evolves dynamically with time, searching for improved customer service levels and lower costs (Carvalho, 2001). These systems have management problems. In the 60's Forester (1961), analyzing the simulation of goods and information flows in a production-distribution system, made up of a factory, a distributor, and a retailer, concluded that, if the demand of products was transmitted along a series of inventories using stock control ordering, the demand variation would increase with each transfer.

This demand behavior is termed *bullwhip effect* or *whiplash effect* (Lee, 1997) and describes how real demand information can be distorted as it is interpreted, processed and propagated upstream in the chain. Although the bullwhip effect has been largely studied lately, it stills exists as a real problem in the supply chain environment and leads to several operational inefficiencies (Lee, 1997). These inefficiencies lead to high cost policies due to their correction with overtime and inventory investment. Understanding bullwhip causes helps to manage them, to find possible strategies to mitigate the inefficiencies, thus improving the supply chain performance. According to its management strategy a supply chain can be classified in two manners: centralized management and decentralized management (Lee and Billington, 1993; Simchi-Levi *et al,* 2000: Azevedo e Souza, 2000).

The Centralized Decision Management Strategy (CDM) is composed of coordination level and enterprise level. At the coordination level, the decisions on how much, where and when to produce are made centrally, by the coordinator, based on material and demand status of the entire system. The objective is to optimize the supply chain production and transportation cost according to a predefined service-level. This management strategy is used mainly when the network is owned by a single entity or has a dominant player as the enterprise assembler in the automotive or electronic chains. Decentralized management, on the other hand, refers to cases where each individual unit in the production chain makes its decisions identifying its most effective strategy considering or not the impact on the other partners enterprises. This approach does not guarantee that the final solution will be optimum solution for the supply chain. Every supply chain is a mixture of centralized and distributed management with several possible business and management configurations. The way to minimise the complexity of analysing every enterprise and chain objectives, within different horizons and time scale lengths, is through a hierarchical decision system. The integration between hierarchical stages is carried out taking each long-term decision as an assignment or target for the next shorter-term decision co-ordinated on the enterprise space and supply chain space itself.

A computational tool must support the analysis of such complex management problem, with conflicting objectives. Analytical models are appropriate for the logistic management and solve multi-period capacitated production planning and logistic problems together with material requirements taking into account enterprise objectives in terms of profit. Due to the large amount of computer time and some modelling difficulties (including machine failures and demand uncertainties) they are limited to the deterministic linear programming where business rules and random effects are not included. They are employed at the logistic level where the supply chain production-planning problem is represented by a network flow model (Furtado et. al, 2002). At the operational level, discrete event simulation has gained considerable attention (Lee and Billington 1993; Towill et all, 1992). It acts as a predictive tool to help quantify the benefits of production policies and rules but has the drawback of large computational time with the increase of size of the system.

This paper represents the supply chain system as a discrete event, discrete time simulation model to analyze management operation strategies. The next section presents strategies for supply chain management. Section three discusses supply chain information exchange models. Section four defines requirements for a supply chain simulator, while section five compares supply chain policies.

2. STRATEGIES FOR SUPPLY CHAIN MANAGEMENT

Supply chain improvement can be obtained by redesigning the physical process, the information channel, and the decision process. This section presents three scenarios for supply chain management and their effect on the increase in order variability. In the first scenario the retailer is the only one that perceives the actual customer demand information. In the second scenario the information of customer demand is distributed to every partner. In the third scenario every enterprise receives the customer demand information plus direct customer information.

Traditional information sharing, Figure 1.a), consists of: each enterprise has its production policy based on the demand information of its customers (Lee, Padmanabhan and Whang, 1997). In this process of information transference, small variation in customer demand lead to large order swings further up the supply chain. This increase in variation is known as the bullwhip effect and contributes to lowering the competitiveness of the final product. The information exchange configuration of Figure 1.b), the extended demand sharing, distributes the customer demand to every member of the Supply Chain. Each partner uses this information and its local demand history to implement its production and order strategy. In Figure 1.c), distributed information sharing, the enterprises demand information are distributed to the supply chain members. Each enterprise, based on internal rules, processes this information to determine its production and order strategy.

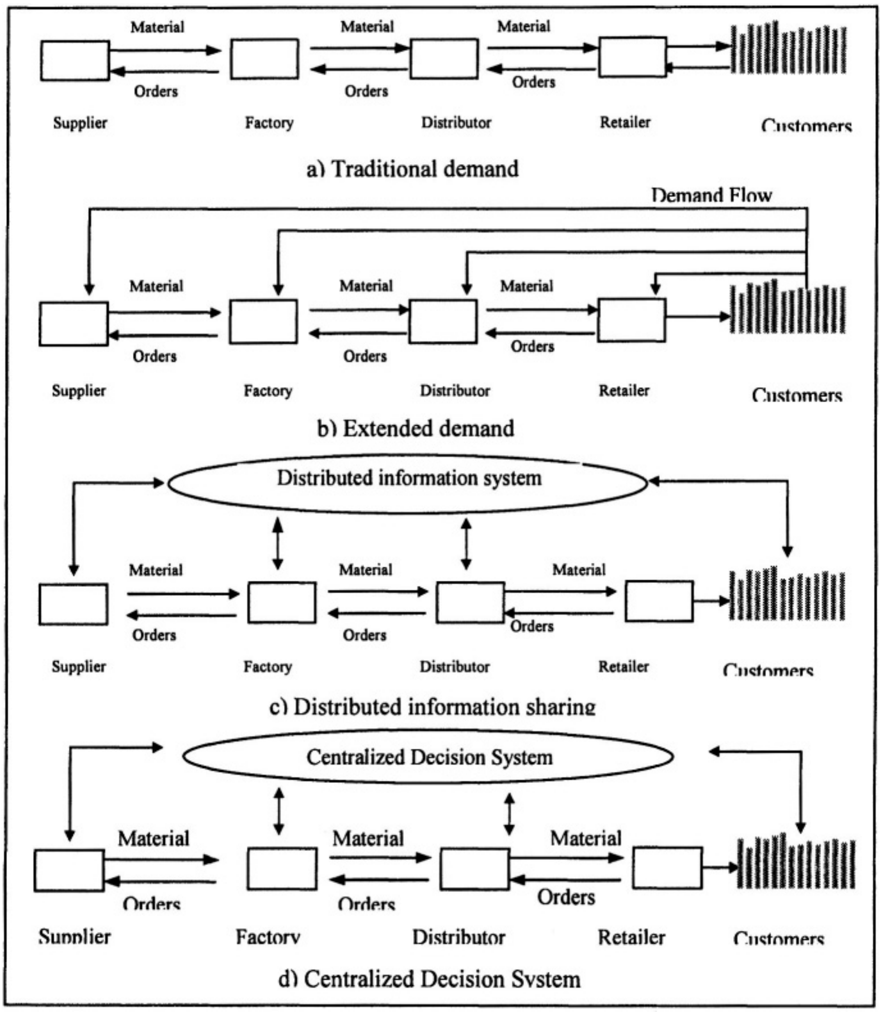

Figure 1 - Information Exchange in a supply chain

The decision hierarchy in the Centralized Decision System, Figure 1.d), is composed of two decision levels. The *coordination level* taken on by the dominant player that negotiates with the others players and establishes targets to be pursued by the partner enterprises and the *enterprise level* where every enterprise has the objective of reaching the targets determined by the coordination level. The operational targets need to be commonly accepted and shared by members. Examples of centralized planning are Assembly plants in the car industry (Fredriksonn, 2002) and mid-tier electronics company (Aenzen and Herbert, 2002). The second possibility is that the task of supply chain management, encountered mainly in clusters, is delegated to a company providing services.

3. SUPPLY CHAIN INFORMATION EXCHANGE LEVELS

Discrete event simulation has been largely used as a tool to model and analyze supply chain management policies. However the computer time of a discrete event models is prohibitive for systems with large number of elements. Also, to represent the business process among enterprises it is necessary to understand that:

- In a large production system, a dozen events occur in a short period of time. However, many of them are self-canceling or can be accommodated within a system slack. Then, only final effects of significant changes must be considered when modeling the business process among enterprises.
- Small changes are important at the enterprise level since they describe the dynamic behavior of the production system and the ability of an enterprise to meet the supply chain objectives. At this level, a precise description of the events through a discrete event representation is necessary.
- Information lead-time is elongated when the planning interval for each pair of partner enterprises differs. Conflicts appear in the planning process in this situation. Then, the first coordination action is to unify the interval for information exchange among enterprises. That means, to establish a fixed discrete time interval to exchange information and to run cooperative planning for the partner enterprises. It results in a synchronous of information exchange.

Two decision levels are identified from the above considerations: The level for coordination and synchronisation of the business process among enterprises and the level to represent the dynamics of the enterprises. At the coordination decision level, events representing decisions such as new information or new material flow among enterprises (sending products, orders, order confirmation, etc.) occur at a discrete time interval. The discrete time information exchange is described in Carvalho (2000) and can be applied to each configuration in Figure 1.

4. THE SUPPLY CHAIN SIMULATOR (SUCS)

A supply chain simulation tool must be simple however not simplistic. It means that the tool must be easy to use and easily manipulated but adequately to represent a supply chain business process. The main points to be considered in the development of a supply chain simulator are:

System Dynamics – The business relationships among enterprises occur at a discrete time interval, thus the simulation tool must simulate the messages exchange among enterprises in a discrete time manner.

Two-Decision Levels – In the distributed decision approach the decisions occur at every enterprise based on business or operation rules. These rules consider inventory level, partner's information (customer service level, customer inventory level, backorder, supplier capacity, etc.). In addition, decisions can occur at supply chain level when considering the Centralized Decision approach. The simulator has to represent a distributed or centralized decision scheme.

Distributed Simulation – The supply chain simulation model has to represent all partners' enterprises. It can be either run in a distributed environment, or in a single computer.

Flexible and Reusable Framework – It should be flexible to represent different supply chain configurations and enterprise roles (supplier, assembler, retailer, manufacturing etc.) to enable rapid development of customized supply chain management application. Models are developed through the use (and reuse) of high level modeling primitives, which encapsulate components (or building blocks) of supply chain models.

The SUCS, (Carvalho and Machado, 2002), is a two level simulation tool for supporting planning decisions of a supply chain which the main characteristic is the representation of the business process among enterprises as discrete time – discrete event driven by decision rules.

5. COMPARISION OF SCM POLICIES

This section analyses three management policies for supply chain composed of a retailer, a distributor and a manufacturer. Service level, inventory level and their standard deviations are used to compare the performance of the policies. The simulation model represents the flow of orders, back orders, materials and products downstream of the chain. Customer demand is represented by a normal distribution function with mean equal to 10 and standard deviation equal to 4. The information, representing orders and back orders, flow upstream, from customer to retailer, from retailer to distributor and so on.

The factory production lead-time is considered constant. Production lead-time and shipment process time are considered constant and equal to 1 period (day, week, turn, etc.). The replenishment lead-time, i.e. the time between the order and the product delivery, is equal to 2 periods for each enterprise. Moving orders average of the last ten periods is used to forecast next period orders for every enterprise.

Policy 1 (P1) models traditional information sharing, where each enterprise adopts the updated s, where:

$$s = L \; x \; AVG + z \; x \; STD \; x \sqrt{L} \quad (1)$$

AVG is the average order of 10 last periods, STD is the standard deviation of order, L is the replenishment lead-time and z is a constant associated with the service level.

The Policy 2 (P2) models inventory policy above, but the s value is based on weighted average of the order and the demand information.

$$s = L\left[\alpha \; AVG_o + (1-\alpha)AVG_d\right] + z\left[\alpha \; STD_o + (1-\alpha)STD_d\right]\sqrt{L} \quad (2)$$

AVG_0 is the average order of 10 last periods, STD_0 is the standard deviation of order, AVG_d is the average demand of 10 last periods, STD_d is the standard deviation of demand, L is the replenishment lead-time and z is the constant associated with the service level.

Policy 3 (P3) models the scenario where the manufacturer has the updated s inventory policy based on the orders received from the distributor. The distributor adopts the updated s inventory level based exclusively on the demand information and manages the retailer inventory (Vendor Managed Inventory). The distributor replenishes, at time interval i, (rep_i), the retailer current demand (rd_i) and the its current backorder (rb_i).

$$rep_i = rd_i + rb_i \quad (3)$$

The analyses bellow is for 500 periods of discrete time-discrete event simulation, $\alpha = 0{,}4$ and z = 97% for equations (1) and (2). In the table 1, the first three columns show the enterprises service levels for each simulated policy. The last three columns show the average inventory level and its standard deviation.

The results of the table 1 shows that Policy 1 decreases service level from the final customer to the manufacturer, as was predictable. Demand amplification occurs when it is transmitted from the customer to upstream in the chain. These behaviors confirm the existence of the Bullwhip and causes lower service level and higher inventory variation. The results of Policy 2 show better service levels of the three echelons. Moreover, their standard deviations have decreased, mainly in the Distributor and the Manufacturer. The weighted average used to control inventory helped to diminish the information distortion.

Table 1 – The strategies comparison

	Service Level (%)			Average Inventory (μ) - Standard deviation (σ)					
Enterprise\ Approaches	P1	P2	P3	P1		P2		P3	
				μ	σ	μ	σ	μ	σ
Retailer	97.6	98.7	99.8	12.4	7.9	11.9	7.2	13.9	5.9
Distributor	94.4	94.9	100	22.5	15.1	13.5	9.5	23.5	7.1
Manufacturer	86.6	97.9	96.8	34.3	23.5	36.8	15.3	24.9	11.1

The Policy 3 results show improvements of Retailer and Distributor service levels and inventory standard deviations of the three echelons. In this scenario, the

Distributor manages the Retailer inventory and eliminates the demand information distortion between these 2 echelons. The Distributor perceives the real demand and replenishes the Retailer inventory efficiently.

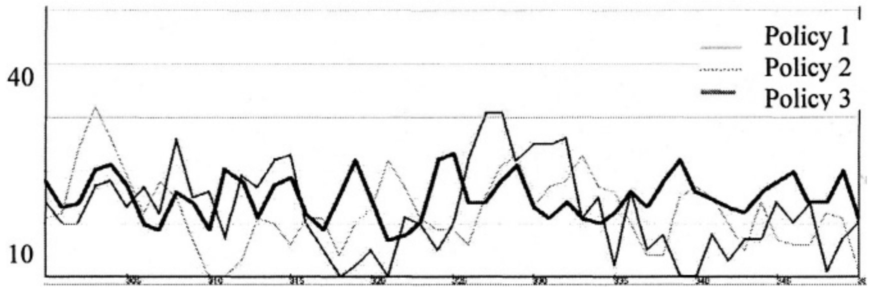

Figure 4 - Variability for the policies in the retailer

Figure 4 shows the behaviour of the inventory for the three policies. It is clear the best performance of Policy 3. Although it maintains a high inventory level in the retailer, the variability measured by standard deviation is significantly lower than the others policies. The same conclusion can be taken to the distributor by analysing the Figure 5. Although the mean is higher than for Policy 2, the standard deviation is 25% less.

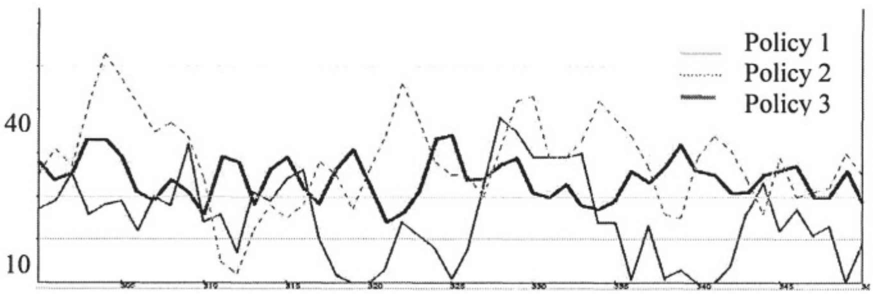

Figure 5 - Variability for the policies in the distributor

The variability in the manufacturer (Figure 6) is high even for the Policy 3 due to the lower information visibility, once the order transfer follows an extended JIT policy.

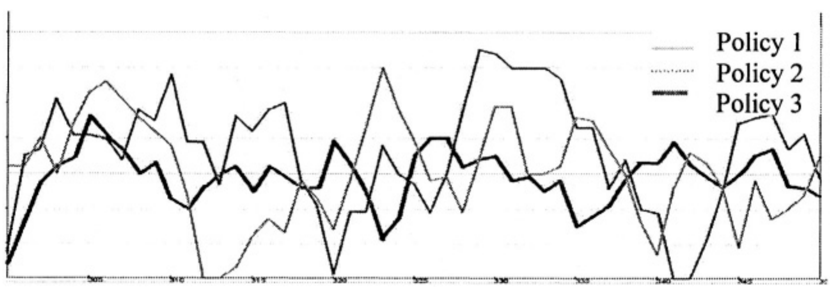

Figure 6 - Variability for the policies in the manufacturer

6. CONCLUSION

This paper analyzed the behavior of a 3-echelons supply chain through discrete time synchronous simulation and shown that poor service levels are strongly related to high standard deviations of inventories and orders. Increasing the supply chain visibility of customer demand information diminished the order variation and as consequence, the inventory level variation and improved the performance of the entire system. The study indicated that smoothing the variability of the orders information and inventory level imply in smoothing the production system.

7. ACKNOWLEDGMENTS

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