A simulation study to quantify opportunities for E-business in a drug distribution system

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Abstract

This paper presents and quantifies some of the opportunities of E-business tools to material flow effectiveness. The study was developed at a Brazilian drug distribution system.

Results are based on comparing historical data against the simulation of an alternative, which manages the distribution process employing an E-business solution embedded with simple replenishment methods to coordinate the flow of materials along the distribution system (manufacturer, wholesalers and drug retailers).

Simulation results show that there is an opportunity to reduce total cost and improve service level to drugstores (and as a result to consumers) at the same time. Another important result was the reduction of the bullwhip effect.

Introduction

This paper is based on a research project on the drug distribution system of a manufacturer in the Brazilian market. The scope of this system begins at the manufacturer's inventory of finished products and ends at the flow of materials towards the drug retailers.

The main objective of this paper is to identify and quantify the benefits of an E-business tool for the distribution system with centralised planning – taking into account the use of cooperation and information sharing practices between the manufacturer and the wholesalers.

It also shows and quantifies the impact of the Bullwhip effect on wholesalers.

The main functions of the E-business tool evaluated using stochastic simulation are: a) a VMI method embedded with a periodic review policy, and b) the reduction of order processing costs.

Bullwhip Effect

Forrester (1958) marks the beginning of the information sharing concept in the management of supply chains to reduce the 'amplification' effect. He showed that information, as well as order variation, spreads with greater volatility when to goes towards the manufacturer in a supply chain. Lee et al.(1997b) called this phenomenon Bullwhip effect.

Lee et al.(1997) identify 4 causes for the Bullwhip effect: Processing the demand variation; Rationing (scarcity); Forming purchase and production lots; Price variations.

Reduction of the Bullwhip Effect

Forrester (1958) suggests three approaches in order to reduce amplification:

1 – speed up the treatment of orders: the reduction of the time involved in executing the activities has some impact on the variation amplitude; however, shortening the supply chain is more relevant.

2 – improve data quality: it is important for the manufacturer to access to the retail sale information.

3 – inventory adjustment: inventory variations can be adjusted not only in the next period, but in a sequence of future periods.

Lee et al.(1997) suggest practices that reduce the Bullwhip effect in each causes pointed out by them:

? Demand processing –demand distortion is due to the suppliers' and manufacturers' lack of visibility regarding final consumption of their products. One way of reducing demand distortion is sharing consumption information with the companies along the distribution chain. However, different forecast methods, used among these companies, could maintain the Bullwhip effect. "In order to eliminate the Bullwhip Effect, is mandatory that there be only one member of the chain carrying out the forecast and purchase activities for the other companies" (Lee et al., 1997, pp. 556)

Lee et al.(1997) also point out practices such as VMI (vendor managed inventory) and CRP (continuous replenishment) as ways to reduce the Bullwhip effect.

Eliminating stages in the distribution chain and reducing the lead times can also mitigate the Bullwhip effect.

? Rationing game – when there is scarcity, the allocation to clients can be performed according to the client's history and not to his orders. Another problem is when a client company tries to protect itself against a possible scarcity; in this case the manufacturer must share inventory and production information. One alternative of avoiding distorted orders is the contractual limitation of the purchase flexibility.

? Forming lots – the reasons to use lots are production and purchase order fixed costs and the use of reviewing periods without the manufacturer following the consumption of its product. Thus, efforts against the Bullwhip effect can be made by reducing order fixed costs employing, for example, automated replenishment systems without the need of issuing orders manually. Regarding the periodic review, making consumption information available to the distribution chain can reduce its effect.

? Price variations – to avoid pricing games every day low price policies can be used. Another alternative is the contractual unbinding between the product purchase and delivery, thus, a large purchase with a discount can be delivered over several future periods.

Simchi-Levi et al.(2000) suggest similar actions to reduce the Bullwhip effect:

? Reducing uncertainty - centralising demand information and supply of each chain echelon, as well complete data on the actual cons umption of the products, can reduce uncertainty.

? Reducing variability – the Bullwhip effect can be diminished by reducing the variability, in each stage of the chain, avoiding, for example, sporadic discounts.

? Reducing replenishment time – the replenishment time enlarges the uncertainty that exits in the forecast process; thus, the shorter this time, smaller the enlargement.

? Forming strategic partnership – the partnerships can reduce the Bullwhip effect by changing the way that information is shared and how replenishment decisions are taken.

Information sharing reduces the Bullwhip effect. Boone et al. (2001) state that centralising sales information makes all the plans in the supply chain react to the same data, reducing, thus, the Bullwhip effect. Gavirne ni et al. (1999) use the inventory management theory in several levels to show that information sharing between supplier and retailers reduces costs significantly. Lee et al. (1998) show that information sharing reduces the demand variation of the supplier and, consequently, reduces the Bullwhip effect. On the other hand, Chen et al. (2000) shows that total information sharing between the companies of the chain significantly reduces the Bullwhip effect, however it does not eliminate it.

Simulation and Inventory Management in the Distribution Chain

According to Ballou (1998), inventories along the distribution chain are rarely independent from each other and inventory management along all the system becomes more important than the management of each independent inventory point. Therefore, problems of this nature become very complex to be dealt with by analytical mathematical models. “The inventory planning through several levels (*echelons)* of the distribution chain is usually performed with the help of computer simulation” (Ballou, 1998, pp. 349).

Slack (1991), when dealing with supply chain management in the manufacturing strategy field, states that “the vertical integration can signify a greater synchronisation of the programmes (...) also helping better forecasts, both of the necessities of the consumers and of the limitations of the suppliers” (Slack, 1991, pp.161).

The advantage of analytical techniques is their capacity to determine directly optimum inventory parameters. On the other hand, analytical techniques depend on limiting assumptions. In simulation, inventory parameters, such as order point or lot size, are entry data for the logistical chain and the inventory policies. The more important results of the simulation are the service level and inventory levels (figure 1).

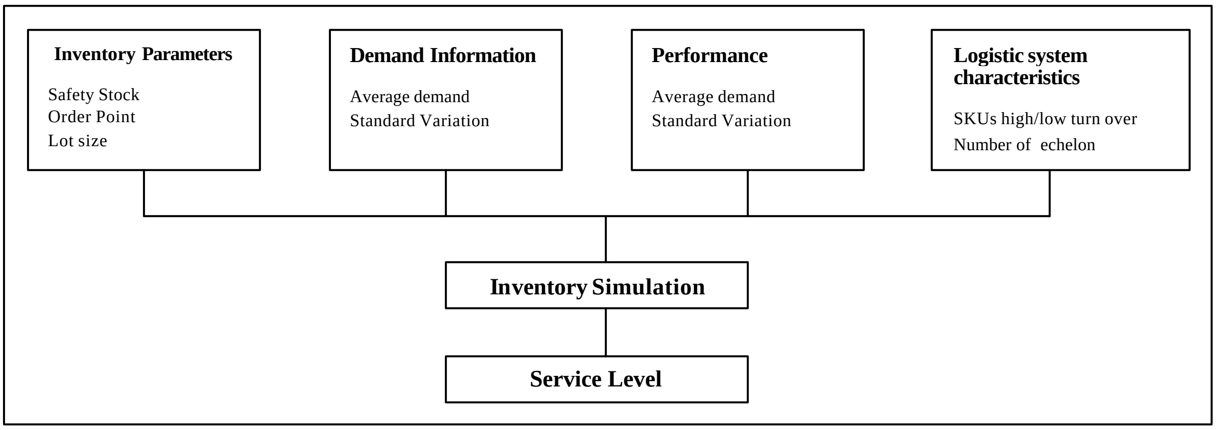


Figure 1. Inventory Simulation (Bowersox, Closs, 1996)

"The greater benefit of the inventory simulation techniques is the capacity of modelling a wide variety of logistical environments without the need of simplifying hypotheses (...). The greater disadvantage of the simulation techniques is their limitation to search and identify optimal solutions (...). The simulation is becoming more popular with the companies trying to understand the dynamics of the stocks in the logistical channel" (Bowersox; Closs, 1996, pp. 573).

Supply chain stochastic models are developed to capture complexities of a multi-product, multilevel, multinational and multi-period problem. "Even small problems can result in complex optimisation problemsd that only can be efficiently valuated using simulation method." (Tayur et al., 1998)

Simulating Inventories – Application to a Drug Distribution Chain

The company, where the study was carried out, supplies an E-business tool that allows wholesalers to send their orders automatically by the Internet. Another product of its portfolio conducts inventory management in the distribution chain using VMI concepts.

Four products were simulated, representing different demand standards: one product of winter seasonality, another of summer sales, one new offering, and a product whose demand is relatively constant during the whole year.

Description of the Physical System

The simulation model of the drug distribution chain was developed in a mirror format, i.e., two chains were developed. One represents the flow material that really occurred, during 2000 ("Historical" subsystem). The second chain represents a configuration where the flow of materials follows an alternative inventory policy that we intend to test ("Policy being tested").

Each one of the chains has a manufacturer that produces the drug and 81 wholesalers who distribute these drugs to the drug retailers (Figure 2).

Representation of the Simulated System

The simulation model proposed has basically three flows of materials as can be seeing in Figure 2. These flows are coordinated by two sets of rules in the simulation model. In the first set the flows are coordinated by the history of the transactions occurred during 2000. In the second set of rules, the inventory management policy that we intended to test is contemplated. An automated replenishment policy with periodical review was used (Table 1).

Table 1. Inventory Policies in the two scenarios

	History	**Policy being Tested**
Flow 1	Order point	Order point
Flow 2	Representation of what happened in the past (historical data)	Periodical review
Flow 3	Representation of what happened in the past (historical data)	Representation of what happened in the past (historical data)

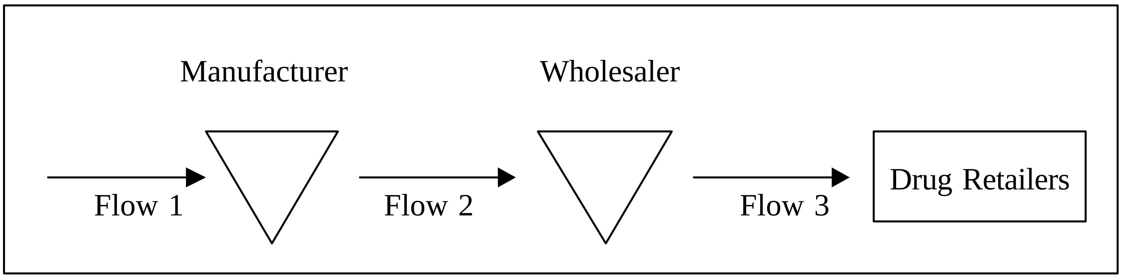


Figure 2 – Simulation Model

In the case of the 'Policy being Tested', weekly forecasts of sales for the drug retailers were performed using a simple moving average of the 20 previous weeks, using weekly season indicators. The daily demand was calculated based on the historical weight (1999) of each day of the weekday.

The following costs were taken into account and calculated by means of the model: Inventory Cost (wholesaler); Inventory Cost (manufacturer); Order Cost (manufacturer + supplier).

Figure 3 shows the case of a product with constant demand during the whole year. The (actual) sales to the drug retailers during the whole year are relatively constant; meanwhile the purchasers of the wholesalers are irregular, generating a bullwhip effect.

In Figure 3, the Order (History) curve indicates the quantity of the drug ordered from the manufacturer according to the historical data of 2000. Order (Policy) indicates the quantity ordered from the manufacturer according to the test policy and Wholesalers Demand is the quantity that the wholesalers really sold each day according to the historical data.

Using the automated replenishment, the profile of the wholesalers' orders becomes less irregular during the year without the ups and downs shown by the order historical data of 2000. With the automated (and frequent) replenishment the wholesalers' orders get nearer of the sales curve to the drug retailers, as can be seen in the detail of Figure 3.

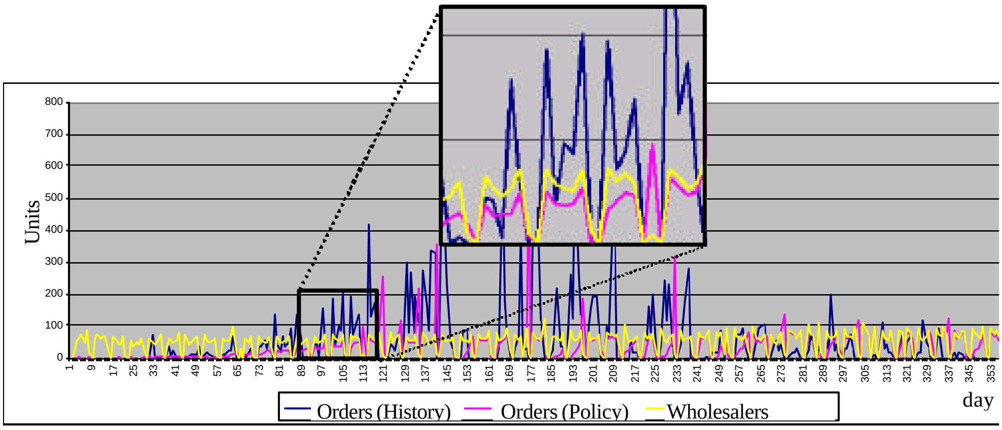


Figure 3 – Wholesaler Orders and Demand

To quantify the Bullwhip effect the indicator proposed by Chen et al. (2000) is used:

$$I_{bullwhip} = \frac{Var(q)}{Var(D)}$$

Where,

q represents the size of the orders made by the wholesalers to the manufacturer, and;

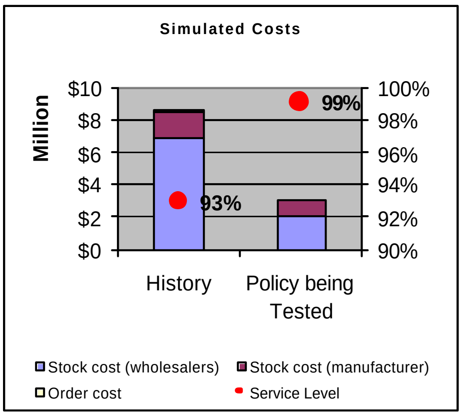
D represents the size of the orders made by the drug retailers and delivered by the wholesalers.

Results

In the simulations carried out for the 4 products the possibility of reducing the average inventory with increases of the Service Level for the drug retailers and, consequently, for the final consumers, was verified. However, the number of orders received by the manufacturer was multiplied by 5.

Without taking into consideration the transport cost, the sum of the other costs decreased around 60%.

This reduction in the cost occurred basically as a result of the decrease of the inventory along the distribution chain.



Using the E-business tool the unit cost of the order is reduced. The simulation result showed that even with the increase of the number of orders the total cost of orders was reduced.

The table on the side shows that even if the variance spread decreased, it continues to occur for all the simulated products.

	$I_{bullwhip}$	
Product	History	Policy Tested
A	6,2	3,6
B	6,0	2,8
C	6,5	2,8
D	10	2,5

Limitation of the model

The cost of transport was not simulated and its increase is expected as the number of deliveries grew more than 400%. However, its consideration must take into account the joint replenishment of all the manufacturer's products to the wholesalers and the use of a milk-run schedule.

The consideration of only 4 products did not make possible the simulation of forming daily loads for each wholesaler. This analysis might show increasing reorder frequency feasibility.

The Bullwhip effect reduction generates an opportunity to improve manufacturer inventory management that was not quantified in the model.

A hypothesis considered is the use of cooperation and information sharing practices between the wholesalers and the manufacturer. However, that is not the current practice of this industry in Brazil.

Conclusions

The study showed that the use of sale forecast and inventory management models (even simple ones) may incur in relevant benefits over current practices adopted by the drug market, allowing the reduction of supply chain costs and the improvement in the products' availability at the same time.

The policy proposed reduced the Bullwhip effect because it: 1-eliminated the large orders resulting from price variations; 2-reduced the fixed ordering costs by using an electronic and automated order system; 3-increased the demand visibility by the use of VMI. However, as has been stated in the literature, the effect continued to exist.

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