

Some Models for Understanding the Incentives for Supply Chain Collaboration

Henry C. Co
Technology & Operations Management
California Polytechnic & State University
3801 W. Temple Ave., Pomona. CA 91768
hco@csupomona.edu

Sharafali Moosa
Department of Decision Sciences
National University of Singapore
10 Kent Ridge Crescent
Singapore 119260

Abstract

The need for information sharing has been increasing as a consequence of the globalization of production and sales, and the advancement of enabling technologies. Yet, beyond resolving the technical issues associated with information sharing and joint decision making, a greater challenge is for the supply chain partners to understand the “lost value” due to uncoordinated decision-making, and more importantly, to determine how the recovered value will be shared among the participating stakeholders. This paper presents some models for understanding the incentives for supply chain collaboration, and describes the enabling technologies for collaborative demand planning and replenishment.

1. Introduction

Synchronizing the supply chain from raw materials to the consumer offers the greatest opportunity to improve profitability and provide greater value to the consumer. It is quickly becoming the standard for competition.

1.1 The Bullwhip Effect

A well-balanced and well-practiced relay team is more competitive when each runner knows how to be positioned for the hand-off. The relationships are the strongest between players who directly pass the baton, but the entire team needs to make a coordinated effort to win the race [4]. Unfortunately, stakeholders along the supply chain have different and frequently conflicting objectives. Accordingly, the stakeholders often operated independently, resulting in a phenomenon called the *bullwhip effect* on demand and supply [14], [15], [3], [6]. As a result of the *bullwhip effect*, orders to the supplier tend to have larger variance than sales to the buyer (i.e. demand distortion), and the distortion propagates upstream in an amplified form.

1.2 Supply Chain Collaboration

Supply chain collaboration requires industry-wide process and data standards for information exchange. It requires a reliable and secure data exchange medium to facilitate collaborative decision making. Electronic data interchange (EDI) was an initial attempt towards facilitating communication between trading partners. With the advent of the Internet, business documents could now be quickly and securely exchanged. Organizations such as RosettaNet have developed

standards and guidelines for automatic system-to-system exchange of business information and transaction [7].

1.3 Incentives for Supply Chain Collaboration

Enabling collaborative supply chain goes beyond resolving the technical issues associated with information sharing and joint decision making. Perhaps a bigger challenge is for the supply chain partners to understand the “lost value” due to uncoordinated decision-making, and more importantly, to determine how the recovered value will be shared among the participating stakeholders.

For example, in collaborative forecasting, if there is no incentive to bind the customers to their forecasts, the customers may be motivated to over-forecast to raise the likelihood that the supplier will have sufficient stock should the customers require more. On the supplier side, if information provided to the customers about the supplier’s allocation is not binding, if the supplier’s situation changes, it could change the allocation at the last minute.

This paper presents some models for understanding the relationships between demand distortion and safety-stock level, and describes the enabling technologies for collaborative demand planning and replenishment.

2. B2B Means “Belly-To-Belly”

The need for information sharing has been increasing as a consequence of the globalization of production and sales, and the advancement of enabling technologies. Improving supply chain efficiencies means the companies should direct their focus outside of the four walls of their enterprises. E-business technology is beginning to restructure the ways businesses conduct business. Yet, no matter how much has changed in the *new economy*, business is still a function of the same reciprocal, collaborative process of decision-making that defined commerce centuries ago and still applies to today's multinational trade. Supply chain collaboration is not, and will never be conducted within the confines of the impersonal, anonymous environments of computer workstations. As Palmer aptly puts it, B2B may as well stand for “belly-to-belly” [11]!

2.1 Inter-Organizational Information Sharing

Collaborative demand planning begins with information sharing. Information sharing can occur within an organization (intra-organizational) as well as across organizations (inter-organizational).

A widely cited benefit of information sharing is that it can dampen the *bullwhip* phenomenon. The *bullwhip effect* often results in excess cost, such as inventory cost, transportation cost or excess raw materials cost due to unplanned and unbalanced production. Using simulation and analytical research, [8] shows that sharing “sell-through” data and inventory information from downstream stakeholder might reduce the bullwhip effect on upstream stakeholders.

Inter-organizational information sharing is at the core of today's most important business strategies, including Web enablement, supply chain management (SCM), customer relationship management (CRM), multichannel and mobile computing, and self-service applications. Inter-organizational information sharing employs collaboration techniques to create a multi-echelon supply chain involving the focal organization and additional suppliers and customers. At present, the most popular collaboration models include the Collaborative Planning, Forecasting and Replenishment (CPFR) model [5], and RosettaNet-based software solutions like WebLogic [2].

CPFR is a set of guidelines supported and published by the Voluntary Inter-industry Commerce Standards (VICS) Association. Trading partners share their plans for future events, and then use an exception-based process to deal with changes or deviations from plans. By working on issues before they occur, both partners have time to react.

A supplier can build inventory well in advance of receiving a promotional order and carry less safety stock at other times. A retailer can alter the product mix to reduce the impact of supply problems.

RosettaNet is an independent, self-funded, non-profit consortium founded in 1998. The consortium is dedicated to the development and deployment of standard electronic commerce interfaces to align the processes between IT supply chain partners on a global basis.

As of April 1999, the RosettaNet Managing Board consists of 34 CEOs, CIOs, and executives representing global members of the IT supply chain, including initial board member companies: American Express, CHS Electronics, Cisco Systems, CompUSA, Compaq, Computacenter, Deutsche Financial Services, EDS, Federal Express, GE Information Services, GSA, Hewlett-Packard Co., IBM, Ingram Micro Inc., Insight, Intel, Microage, Microsoft, Netscape, NEC Technologies, Oracle, pcOrder, SAP AG, Tech Data, Toshiba Information Systems and United Parcel Service(<http://xml.coverpages.org/rosettaNet.html>).

2.2 Intra-Organizational Information Sharing

Intra-organizational information sharing occurs at the data level and at the business-process level. These two levels of information sharing have been widely studied by SCOR [12] and RosettaNet (www.rosettanet.org). Solutions such as RosettaNet rely heavily on the definition of EDI-like standards for the exchange of data, process knowledge, messages, etc. [2].

Intra-organizational information sharing means creating or modifying the interactions among semi-autonomous but related application systems, encompassing purchased packages, legacy applications and new Web services. This is generally realized through ERP or middleware serving as an information backbone to transact and convert data among disparate systems.

Enterprise Application Integration (EAI) links together diverse systems and applications across the enterprise, allowing the organization to keep pace with and respond to market changes [9]. An enterprise resource planning (ERP) system, on the other hand, provides an integrated transaction processing fabric for an organization, which enhances organizational performance by reducing information inconsistency and by improving transaction-processing efficiency.

3. Incentives For Collaboration

In [13], Sharafali and Co showed that significant savings in inventory-related costs could be achieved if the buyer and the seller cooperate. In analyzing the buyers' and the sellers' replenishment decisions, the authors pointed out that only the supplier benefits from such cooperation. In order to motivate the buyer to cooperate, the authors considered some cooperative strategies. These include the analysis of the impact of (1) price changes, (2) discount policies, and (3) partial deliveries. The authors showed that the *partial deliveries* strategy is preferable. This is in tune with the benefits cited in the literature as a result of JIT-like relationship between the two parties concerned.

Due to the *bullwhip effect*, suppliers often have to deal with a demand patterns that are perceived to be erratic and cyclical. The variability of demand increases in moving up the supply chain from consumer to retailers to distribution center to central warehouse to factory. This section provides some models for understanding the advantages of cooperation between the supplier and the buyer: collaborative demand planning.

3.1 Optimal Safety-Stock

Uncertainties in lead time and demand exert considerable influence on the stability and credibility of inventory control systems. There are various strategies for coping with the many sources of uncertainties. Murthy and Ma [10] provide an excellent review along with the possible research directions for coping with uncertainties in Material requirements planning systems.

Let Y_t = replenishment quantity at period t , for $t = 1, 2, \dots, n$, where n is the length of the planning horizon. The current period is $t=1$. If the lead time = L , then Y_t , for $t = 1-L, 2-L, \dots, 0$, represent the on-order quantities that are expected to arrive in periods 1, 2, ..., $L-1, L$ respectively.

Let I_{t+L-1} = beginning inventory at period $t+L$. If the forecasted demand for period $t+L$ is μ_{t+L} , the replenishment quantity made L periods ago should at least be equal to $\mu_{t+L} - I_{t+L-1}$ (Otherwise, there would be a

shortage). Supposed the desired safety stock for period $t+L$ is s_{t+L} , then $Y_t = [\mu_{t+L} + (s_{t+L} - I_{t+L})]^+$. Let $s_{t+L} = \beta_{t+L}\mu_{t+L}$, i.e., the safety stock is a fraction of the forecasted demand. Then,

$Y_t = [(1 + \beta_{t+L})\mu_{t+L} - I_{t+L-1}]^+$. In the literature, the β_{t+L} is often referred to as the *overplanning* factor.

The actual demand D_t is stochastic and non-stationary. Let G_t = demand distribution is with mean μ_t and standard deviation σ_t . Assume the demand sequence $\{D_t, t = 1, 2, \dots\}$ to be mutually independent. We assume that the forecast for each period t is unbiased and is equal to μ_t . Since demand is non-stationary, the optimal production ordering quantities vary over the planning horizon. In practice, under such an environment, decisions are usually made on a rolling horizon basis. That is, each time a period has passed, it is dropped from the planning horizon, and the forecast demand for a new period is added at the end of the forecast window.

Suppose demand not met are backordered at a cost of p \$/unit; and the unit inventory holding cost is h \$/unit. If the ending inventory in period t is I_t , the total inventory cost for period t is $h[I_t]^+ - p[I_t]^-$, where $[I_t]^+ = \max(0, I_t)$ and $[I_t]^- = -\min(0, I_t)$. The optimal replenishment problem is to determine Y_t , for $t = 1, 2, \dots, n$, such that:

$$\begin{aligned} \text{Min} \\ \beta_{L+1}, \beta_{L+2}, \dots, \beta_{L+n} \quad E[TC] = \sum_{t=1}^n [hE[I_{t+L}^+] - pE[I_{t+L}^-]] \end{aligned} \quad (1)$$

Subject to:

$$\begin{aligned} I_{t+L} &= I_{t+L-1} + Y_t - D_{t+L} \\ Y_t &= [(1 + \beta_{t+L})\mu_{t+L} - I_{t+L-1}]^+ \\ \beta_{t+L} &\geq 0, \text{ for } t = 1, 2, \dots, n. \end{aligned} \quad (2)$$

The objective function (1) is convex (see [1]). Solving

$$\begin{aligned} \frac{\partial}{\partial \beta_{t+L}} E[TC] = 0 \quad \text{leads to} \\ G_{t+L}((1 + \beta_{t+L})\mu_{t+L}) = \frac{p}{p+h}, \quad t = 1, 2, \dots, n. \end{aligned} \quad (3)$$

Note that (3) is true for any lead-time L , for simplicity we assume that $L = 0$. As we have a rolling schedule, we plan for the replenishment quantity for the current period, i.e., we consider $t = 1$. Equation (3) then

$$\text{becomes: } \beta_1 = \frac{1}{\mu_1} G_1^{-1}\left(\frac{p}{h+p}\right) - 1. \quad (4)$$

We note that the successive overplanning factors are constant if the sequence of demands are *independent and identically distributed* (i.i.d.).

3.2 Forecast Errors and Safety-Stock

Suppose D_n is *exponentially distributed*,

then $G_n(x) = 1 - e^{-\mu_n^{-1}x}$, $x > 0$.

Then $\left[1 - e^{-(1+\beta_1)\mu_1^{-1}}\right] = \frac{p}{h+p}$, or $e^{-(1+\beta_1)\mu_1^{-1}} = \frac{h}{h+p}$.

Hence, $\beta_1 = -\mu_1 \ln \frac{h}{h+p} - 1$

or $\beta_1\mu_1 = \mu_1^2 \ln \frac{h+p}{h} - \mu_1$. The optimal safety stock

is a quadratic function of the sales forecast! Clearly, this can be seen as the worst-case scenario. If the demand distribution is *exponentially distributed*, the level of uncertainty as measured by the variance is as large as the forecast itself (the mean).

Suppose D_n is uniformly distributed over (a_n, b_n) , then

$$G_n(x) = \begin{cases} \frac{x - a_n}{b_n - a_n}, & a_n < x < b_n \\ 1, & x \geq b_n \\ 0, & \text{otherwise} \end{cases}.$$

It can be shown that the optimal safety stock $\beta_1\mu_1 =$

$$\frac{(p-h)(b_1 - a_1)}{(p+h)(b_1 + a_1)} \mu_1$$

Apparently $0 < \beta_1 < 1$. This guarantees that the safety-stock level will never exceed 100% of forecasts.

Moreover, if the forecasts are unbiased, then $(b_1 + a_1)/2 =$

μ_1 , the optimal safety stock is $2 \cdot \frac{(p-h)}{(p+h)} \cdot (b_1 - a_1)$,

i.e., the optimal safety-stock level is directly proportional to the forecast error $= \kappa \cdot (b_1 - a_1)$. It is noteworthy that as inventory-holding cost approaches backordering cost, the need for safety stock diminishes.

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