DECISIONS IN A SUPPLY CHAIN MODELING FOR COMPARATIVE EVALUATION STRATEGIES IN MULTIPLE BUYERS

CH. SRINIVAS
Mechanical Engineering Department, Vaageswari College of Engineering, Karimnagar, INDIA

ABSTRACT

This paper evaluates the impact of different strategies on the performance of a supply chain to optimize the supply chain cost and simultaneously optimize other decision variables such as quantity transported, number of shipments, fill rate. We have found that the results are more attractive and competitive.

Keywords: Consignment Inventory, Delay Delivery, Information Sharing, Lead Time, Supply Chain Performance.

1. INTRODUCTION

More and more companies have recognized that there is a direct link between the performance of supply chains and the availability inventory is one of the most widely discussed issues for improving SC efficiency. It is widely known that Wal-Mart and Procter & Gamble (P&G) more strategic analysis regarding the retail sales of P&G products at Wal-Mart stores. Thus P&G done a better job of managing its production and provides Wal-Mart with greater “in store” availabilities. Furthermore, new successful companies such as Dell and Cisco are following new stochastic strategies with suppliers and customers to reduce working capital and inventories.

Supply chain management (SCM) has become one of the most important strategies for achieving competitive advantage in different industries in the last decade. Researchers have investigated various processes in the planning and development of supply chains. However, increasing attention has been placed on performance, design and analysis of supply chain models.

Consignment inventory is among various new inventory strategies in which the vendor stocks his finished products in buyer’s warehouse but maintains title to the products until sold and then the payment is made to vendor. Furthermore, the vendor will guarantee for the quantity stored in the
buyer warehouse that will be ranging freely in quantity between a minimum and maximum inventory level with supporting shortages in stochastic demand. In other words, even if the products are stored in the buyer’s warehouse, it is still ‘owned’ by the vendor. The transfer of ownership will take place only at the time when the customers will pick up the items. The basic fundamental of consignment inventory is explained in detail in Braglia and Zavanella [2003], whereas principles and modeling of consignment inventory are discussed in Valentini and Zavanella [2003], Simone and Grubbström [2004], Chidurala Srinivas and Rao, C.S.P [2010], Srinivas Ch, Rao CSP [2007] with reference to deterministic demand and to its extension to a stochastic environment.

2. STRATEGIES IN CONSIGNMENT INVENTORY

The consignment inventory has been analyzed for three different models for single vendor – multi buyers: basic consignment inventory, consignment inventory with delay deliveries, consignment with information sharing with delay deliveries.

The necessary notations used in this paper are summarized as follows:

- **Av** batch set-up cost ($) (vendor)
- **Ab** order emission cost ($) (buyer)
- **hv** vendor stock holding cost ($) / unit / unit time
- **hb** buyer stock holding cost ($) / unit / unit time
- **p** vendor production rate (continuous)
- **di** demand rate in units per unit time seen by the buyer (continuous)
- **σ** standard deviation of demand / unit time
- **π** unit back order cost ($) for the buyer
- **Li** length of the lead-time for the buyer
- **ϕ** normal probability density function
- **Φ** cumulative distribution function
- **n** number of transport operations / production batch
- **mi** delayed deliveries shifted to another buyer (≤ k1)
- **jij** delivery shifted from ith buyer to jth buyer, ∑jij = mi
- **y** buyer range
- **z** safety factor
- **k1** delay deliveries (≤ n)
- **C** Production cycle time for vendor
- **S** Setup time
2.1 Basic Consignment Inventory

This is a model in which basic concepts and a condition of the consignment inventory policies has been implemented. The joint total expected cost in this strategy is summarized as:

\[
\text{JTEC}_{CI} = \frac{s}{c} + h_i \frac{c}{2p} \left( \sum_{i=1}^{n_i} \frac{D_i^2}{n_i} \right) + \frac{1}{c} \left( \sum_{i=1}^{n_i} A_i + \sum_{i=1}^{n_i} n_i A_i \right) + \sum_{i=1}^{n_i} \left( \frac{h_{bi}}{2} \left( D_i c - (n_i - 1) D_i \right) \right)
\]

\[
\left[ \frac{D_i c}{n_i p} + \sum_{j=1}^{n_i} \frac{D_j c}{n_j p} \left( \frac{n_j}{n_i} \right) \right] \right) \right) \right) + \frac{1}{c} \sum_{i=1}^{n_i} \left( h_{bi} z \sigma_i \sqrt{L_i} \right) + \frac{1}{c} \sum_{i=1}^{n_i} \pi_i \sigma_i \sqrt{L_i} \psi(z) \right) \right)
\]

(1)

2.2 CI-k1 model (delayed deliveries, k1< n)

In this model, the last delivery in the corresponding cycle will be delayed until it reaches that there is no longer an increase in the maximum level already reached. The supply chain model is constructed in such a way to fulfill the condition drawn. The joint total expected cost in this strategy is expressed as:

\[
\text{JTEC}_{CI-k1} = \frac{1}{c} \left[ s + \sum_{i=1}^{n_i} \left( A_i + n_i A_i \right) \right] + H(n)c + \sum_{i=1}^{n_i} \left( h_{bi} z \sigma_i \sqrt{L_i} \right) + \frac{1}{c} \sum_{i=1}^{n_i} \left( \pi_i \sigma_i \sqrt{L_i} \psi(z) \right) \right)
\]

(2)

where,

\[ H(n) = h_i \left[ \frac{1}{2p} \left( \sum_{i=1}^{n_i} \frac{D_i^2}{n_i} \right) \right] + \sum_{i=1}^{n_i} \left( \frac{D_i}{n_i} \left( \frac{p - D_i}{n_i} \right) \left( k_i + 1 \right) \right) \right) \right)
\]

\[ + \sum_{i=1}^{n_i} \left( \frac{h_{bi}}{2} \left( n_i - k_i \right) \frac{D_i}{n_i} - \left( n_i - k_i - 1 \right) \frac{D_i}{n_i} \right) \right)
\]

2.3 CI with information sharing and with delay (CI-IS-k1)

In an integrated information sharing model the unwanted scheduled delivery of a particular buyer will be shifted to another buyer. However in the shifting process, the quantity shipped is same, as the quantity required to him at that time, for this the vendor will make adjustments from his stock. This technique makes feasible only for multiple buyers and the supplier to be linked together to all buyers on a real time basis and hence it is possible for the supplier to monitor the consumption pattern of the buyers. The joint total expected cost in this strategy is summarized as:

\[
\text{JTEC}_{CI-IS-k1} = \frac{s + \sum_{i=1}^{n_i} A_i + n_i A_i}{c} + h_i c \left[ \frac{1}{2p} \left( \sum_{i=1}^{n_i} D_i^2 \right) \right] + \sum_{i=1}^{n_i} \left( \frac{D_i}{n_i} \left( \frac{p - D_i}{n_i} \right) \left( k_i - m_i + 1 \right) \right) \right) \right)
\]

\[ + \sum_{i=1}^{n_i} \left( n_i - k_i \right) \frac{D_i}{n_i} \left( \frac{p - D_i}{n_i} \right) \left( k_i - m_i + 1 \right) \right) \right)
\]

\[ + \frac{1}{c} \sum_{i=1}^{n_i} \left( h_{bi} z \sigma_i \sqrt{L_i} \right) + \frac{1}{c} \sum_{i=1}^{n_i} \left( \pi_i \sigma_i \sqrt{L_i} \psi(z) \right) \right) \right)
\]

(3)
2.4 Chromosomes for various models are summarized below:

\[ CI : (c, n_1, n_2, \ldots, n_m, \Phi(z)) \]

\[ CI-k^l : (c, n_1, n_2, \ldots, n_m, k_1^l, k_2^l, \ldots, k_m^l, \Phi(z)) \]

\[ CI-IS-k^l : (c, n_1, n_2, \ldots, n_m, k_1^l, k_2^l, \ldots, k_m^l, m_1, m_2, \ldots, m_m, j_1, j_2, \ldots, j_j, \Phi(z)) \]

The fitness function as the objective function of minimization type we have to modify it to maximization type. Genetic Algorithm is generally designed for maximization problem.

\[ f_t = \frac{1}{1 + JTEC(n, k^l, m, j, c, \Phi(z))} \]

3. NUMERICAL ANALYSIS AND RESULTS

The input data used for this data set is refer Ben-Daya and Raouf [1994], Braglia and Zavanella [2003], Chidurala Srinivas and Rao, C.S.P [2010], Srinivas Ch, Rao CSP [2007] hv=$4 per unit/year, hbi=$5 per unit/year, D1,2 = 1000, 1300 units/year (for two buyers), \((p/\sum D_i)\) ratio  = 3.2, \(\sigma_{1,2} = 44.72, 50, \) \(Av= $400/setup, Abi = $25/order, \sigma = $50/unit.\) This input data is extended upto ten buyers with \(D_{3,4,\ldots,10} = 800, 1000, 1500, 600, 1200, 1500, 1000, 800\) and \(\sigma_{3,4,\ldots,10} = 35.7, 30, 30, 20, 30, 30, 30, 30, 20.\)

Sensitivity analysis has been performed to analyze the results of consignment inventory single vendor - multi buyer models. The sensitivity analyses given through Figures 1 to 6. The numerical results reveal that by having more buyers in the supply chain echelon the total cost savings are increased.

If closer the total demand rate to the production rate, the greater saving can be obtained. In other words, by gradually declining the ratio of production rate to demand rate, percentage of JTEC saving is increased (Figure 5). In opposite, by increasing \(p/\Sigma D\) ratio the JTEC saving is decreasing. Our analysis considers the tradeoff of percentage of savings in JTEC versus \((p/\Sigma D)\) ratio from 1 to 5. It is concluded that the production to demand ratio \((p/\Sigma D)\) of 3.2 is suitable for set of given data after considering fine iterative tuning analysis between \(p/\Sigma D\) ratio of 3 to 3.5. Moreover it is found from the research articles of Goyal [1995, 2000], Hill [1997], Ben-Daya and Hariga [2004], Braglia and Zavanella [2003], Valentini and Zavanella [2003] that they considered production to demand ratio as 3.2. At \(p/\Sigma D\) ratio 3.2.

The consignment inventory with information sharing and with delay delivery (CI-IS-k1) yields lowest JTEC $3120 with four delay deliveries and two shifted deliveries among buyers due to sharing of information. The projected JTEC of single vendor – single buyer from single vendor – ten buyers is CI, CI-k1 and CI-IS-k1 are $938.1, $924.1 and $923.8. In case of deterministic demand, the joint total cost is 6% less in CI, CI-k1 and CI-IS-k model compare to stochastic customer demands. The results of various Figures given are refer to stochastic demands.

From the fundamental principle of CI, that the vendor always prefer to have maximum inventory level at the buyer warehouse hence the maximum buyer inventory in CI model is 651 units. CI-k1 gives lowest buyer maximum inventory because of delaying the last delivery whereas in CI-IS-k1 the buyer maximum inventory is 540. The JTEC of CI-k1 model for all the ranges of
k1 (k1 = 0 to 7) decreases with increasing number of shipment after attaining minimum values again JTEC increases.

For CI-k1 at k1=2 will occur minimum joint total cost $3294 for six shipments, and its maximum buyer inventory is 499 (two buyers). When k1 = 0, CI-k1 ∈ CI ∀ k1=0, is always produces a maximum cost, i.e., if it is adopted basic CI model. The JTEC decreases while increasing buyer maximum inventory and then increases. For k1=2 gives a lower buyer and vendor inventory cost for all the ranges of maximum buyer inventory levels hence the lowest JTEC occurs in this model. When buyer size varies from two to ten, due to information sharing, the buyer maximum inventory is reduced and its minimum inventory reduces after six buyers.

The total shipments delivered to buyer in CI-IS-k1 model is more compare to other models due to sharing of information and this mode gives lowest JTEC cost for single vendor – two buyers due to reduction in total vendor. The JTEC cost increases while increasing buyer size upto six buyers CI-IS-k1 model gives lowest JTEC compare to CI, CI-k1 models. From buyer size five to ten, CI and CI-k1 total costs are almost closely varies.

The delay deliveries decrease in case of CI-k1 while increasing buyer size because more the last deliveries are delayed in the case of more number of buyers. Whereas it increases in case of CI-IS-k1 due to information sharing. The deliveries shifted among buyers due to information sharing in CI-IS-k1 ranges from 2 to 5, while increasing buyer size (Figure 6).

If the strategy is shifted CI to CI-IS-k1 from two buyers to five buyer the % of savings decreases from 8% to 1% and for buyer six the % of savings increase and again for buyer size seven to nine the % of savings decreases to 0%. Where as if CI model is shifted to CI-k1 model for bi, ∀ i<4 the cost savings are about 1-4% savings (Figure 1). If the model is shifted from CI-k1 to CI-IS-k1, the cost savings decreases from 4% to 1% when buyer size increases from two to five, again for buyer size six it increases and later from buyer size seven to 10 the cost savings decreases to zero. In brief, the CI-IS-k1 gives lowest JTEC cost compare to CI and CI-k1 (Figure 2).

![Fig 1: Variation in JTEC while shifting from CI to CI-k1 and CI-IS-k1](image)
Fig. 2: Variation in JTEC while shifting from CI-k\textsuperscript{1} to CI-IS-k\textsuperscript{1}

Fig. 3: Cycle time in days for different strategies

Fig. 4: Minimum – Maximum cycle inventory in CI strategies
Fig. 5: Variation of JTEC while varying in production to Demand ratio

Fig. 6: Total shifted deliveries in CSP-IS-k1 model with increasing buyer size.

4. CONCLUSIONS

The fixation of production to demand ratio is found to be crucial and is very sensitive to total costs apart from other variables. An extensive analysis has been made in this case and finally fixed at p/D ratio of 3.2. The proposed models gives cost savings of approximately 9% compare to Braglia and Zavanella (2003) for different strategies. The proposed models could thus be used to provide good results to the wide variety of data sets. The CI-IS-k1 give lowest total cost compare to CI and CI-k1. It is observed that % of cost savings obtained by CI-k1 and CI-IS-k1 decreases as number of buyers increases.

REFERENCES


