

Optimization of Production System in Supplier - Retailer-Customers based Supply Chain

Raishetty Sridhar^{1*}, K.Eswara Prasad², Ch.Srinivas³

Abstract— This paper presents the production inventory control optimization in production system of supplier – retailer business environment in a Supply Chain. Our results put forward that the proposed model algorithm outperforms the other methods. When ever if need to delivery the items with reduced lead time for customer requirement fulfillment but here an additional cost is added. To solve the problem an iterative procedure is involved for which GA is used and is coded in VC++.

Index Terms— Supply Chain, Optimization, Lead Time, Total Cost, Crashing Cost, Genetic Algorithm, shortage cost, and fill rate

1 INTRODUCTION

In today's globalize economy, business is looking for ways to optimize the supply chain network by means of integration and cooperation of network echelons. Inventory is one of the most widely discussed areas for improving supply chain efficiency. Wal-Mart and Procter & Gamble popularized it in the late 1980's. Since the holding of inventories in a Supply Chain (SC) can cost anywhere between 20% to 40% of product value, hence effective management of inventory is critical in SC operations. Many researchers have provided taxonomies and frame works to help practitioners and academicians to understand the nuances of supply chain management. Houlihan (1985) is credited for coining the term Supply Chain (SC) with insight concepts and a strong case for viewing it as a strategy for global business decisions. Many definitions of SCM have been mentioned in the literature and in practice, although the underlying philosophy is the same. The lack of a universal definition for SCM is because of the multidisciplinary origin and evolution of the concept.

Simchi-Levi et al.(2000) defined SCM as a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouse and stores, so that merchandise is produced and distributed at the right quantities, to the right location and at the right time in order to minimize system wise cost, while satisfying service level requirements. Since the supply chain consists of different echelons; supplier, retailers and customers, hence inventory at different locations has to be maintained to face stochastic demands.

Therefore, inventory has become one of the most widely discussed areas for improving supply chain echelon efficiency. Since the holding of inventories can cost anywhere between 20 to 40% of product value, hence an effective inventory management is critical and most essential (Ballou, 1992).

Supply chain integration has become the focus and goal of many progressive firms and it is used as strategy through which such integration can be achieved. Nevertheless, most quantitative analysis on supply chain management issues is dominated by the framework of multi-echelon serial systems or distribution systems where a relationship between a single vendor and a single buyer or a single vendor and multi buyers is considered. The main issues that have been addressed include deployment of strategies, and control policies. Finally, to survive and hold its position in the market it need to find a method of tactical business strategies which should be on the basis of mutual benefit of supplier, retailer and customers. The problem considered here is typically deals with logistics aspects as well as the inventory level, lead time, and a cost which means a novel approach to mutually benefit suppliers and retailers and also finally customers. The delivery planning is to determine order-up-to level of the supplier and the retailer simultaneously for the objective of minimizing the expected average cost. Impact of Lead time variability is also investigated. The lead time reduction has been viewed as an investment for strategic mutual benefit.

2 LITERAURE REVIEW

Pan and Yang (2002) were credited for minimizing the joint total economic cost of supplier and buyers inventory model with controllable lead time which is a decision variable; however, shortages are not allowed in their paper. Srinivas and Rao (2010, 2007, and 2009) decomposed lead time into four components each having a strategic different crashing cost for reduced lead time. They have proven that the lead time crashing component can be more than three components but it is in

1. SAP PP-QM Consultant, Zensar OBT Technologies, Madhapur, Hyderabad, India, PH-+919849625060. E-mail: sridharrishetty@gmail.com

2. Professor & Principal, JNTUH College of Engineering, Jagityal, India, epkoorapati@gmail.com.

3. Professo & Principal, Vaageswari Engineering College, Karimngar, India. E-mail: c_h_srinivas@yahoo.co.in

the interests of both parties involved in the strategic business.

Hans Siajadi et al. (2006) proposed new multiple shipment models for single vendor multi buyer single product problem. They assumed that the ordering cycle time for each buyer and production cycle time for vendor is same and the order amount for each buyer is delivered in a number of equal size shipments where the frequency and the size of the shipment might be different for each buyer.

The literature review paper of Aytug et al. (2003), Chaudhry and Luo (2005) reveals that no approach attempt has been made to develop a heuristic method such as Genetic Algorithm to determine inventory levels in supply chain echelons. The running time of enumeration technique grows exponentially (Goyal, 1974) while increasing the number of variable. Hence GA method is suggested for more variable problems.

Daniel and Rajendran (2005) studied Genetic Algorithm (GA), enumerate and random search procedure methods to single product serial SC operating with a base stock periodic review system and to optimize the base stock inventory levels in the SC so as to minimize the total supply chain cost, comprising holding and shortage costs at all the installations in the SC. They found the solution generated by the proposed GA is not significantly different from the optimal solution yielded by complete enumeration, but it is significantly good for deterministic replenishment lead times and the other with random replenishment lead times. They did not check for multi buyer stochastic demand and lead time models.

Huayu et al. (2009) has developed a model using both GA and Simulated Annealing to address problems in logistical distribution centers and its aspects of distribution centers, several customers, and different demand of customers and vehicles with capacity constraints in view of minimizing the total travel cost. This paper mainly focuses on scheduling and routing decision for shipment. The paper describes method to allocate shipment based on present and predicted demand. They proposed a new concept of latest departure time for shipment delivery.

The recent paper of Srinivas and Rao (2010) reveals that a quantitative analysis using GA gives significant results when decision variables are more and the computational CPU time will be less compare to enumeration technique. They conclude the inventory management policy with controllable lead time is suitable for facing new SCM challenges with random demand. The proposed models not only can make tradeoffs for mutual benefit but can also enable decision makers to deal systematically.

3 MODELING

In this paper we consider a model that involves single supplier - single retailer and multi customers.

3.1 Assumptions and Notations

Note that the supplier does not have direct connection with customers. Hence we consider the model as two serial vender-

buyer models, where in the supplier-retailer part we take the supplier as vender and the retailer as buyer, while in the retailer-customers part we consider it as single vender-multi buyer model. Analysis of both parts is shown as follows.

Part I: Single Supplier - Single Retailer

P supplier production rate (continuous), items per unit time
 D demand rate seen by the retailer (continuous), items per unit time
 n number of delivery batches, from which the period between two orders is c/n
 Q quantity transported per delivery batch, given $Q=Dc/n$
 s supplier setup cost
 T transportation cost per delivery batch from supplier to retailer
 L_k lead time for each order / delivery, $k=1,2,\dots,n$
 h_1 supplier stock holding cost per item per unit time
 h_2 retailer stock holding cost per item per unit time

Part II: Single Retailer-Multi Customers

I_s safety stock for retailer,

$$I_s = \min_i \{ D_i L + z \sigma_i \sqrt{L} \}$$
 m number of customers
 D_i demand rate seen by customer i (continuous), items per unit time
 s' retailer setup cost
 C_s shortage cost per item
 n_i number of delivery batches to customer i , hence the inter arrival time is c/n_i
 Q_i quantity transported per delivery batch to customer i , given $Q_i = D_i c / n_i$
 T_i transportation cost per delivery to customer i
 Overall assumptions and notations are:
 c supplier production rate (continuous), items per unit time
 x items, in this paper we consider single item.

3.2 Model Formulations

The objectives are: (i) to minimize the total cost; (ii) to minimize the total shortage cost; (iii) to minimize the total lead time penalty; and (iv) to maximize the fill rate. The decision variables considered in this work are: (n, n_i, L_k) .

The Total Cost is,

C_{total} = supplier setup cost + supplier holding cost + supplier-retailer transportation cost + lead time penalty + retailer hold-

ing cost + retailer setup cost + retailer safety cost + shortage cost + retailer-customer transportation cost

each part of which can be calculated as below:

supplier setup cost: $C_{setup}^S = sn$ (1)

supplier holding cost: $C_h^S = h_1 \frac{c^2}{2} \left(P - \frac{n-1}{n} D \right)$ (2)

supplier-retailer transportation cost:

$C_{Trans}^{SR} = Tn$ (3)

lead time penalty:

$C_{LT} = \sum_{k=1}^n C_{L_k}$ (4)

where each C_{L_k} can be calculated as [see Srinivas and Rao (2010)]:

$C_L = c_u (L_{u-1} - L) + \sum_{w=1}^{u-1} c_w (b_w - a_w)$

$L_u = L_0 - \sum_{w=1}^u (b_w - a_w)$ and $L_u < L \leq L_{u-1}$
 retailer holding cost: $C_h^R = h_2 \frac{c^2}{2} \left(D - \sum_{i=1}^m \frac{n_i - 1}{n_i} D_i \right)$ (5)

retailer setup cost: $C_{setup}^R = s' \sum_{i=1}^m n_i$ (6)

retailer safety cost: $C_{safety}^R = h_2 c I_s$ (7)

shortage cost: $C_{short}^R = C_s \left(\sum_{i=1}^m Q_i - Q \right)$ (8)

where

$C_s = \begin{cases} 0.5C_s^0, & \sum_{i=1}^m Q_i - Q > \frac{1}{m} \sum_{i=1}^m Q_i \\ C_s^0, & \sum_{i=1}^m Q_i - Q \leq \frac{1}{m} \sum_{i=1}^m Q_i \end{cases}$, C_s^0 is the basic

shortage cost per item

Retailer-customer transportation cost:

$C_{trans}^{RC} = \sum_{i=1}^m T_i n_i$ (9)

Note that the transportation cost also varies whenever a shortage occurs,

$$T_i = \begin{cases} \alpha T_i^0, & \sum_{i=1}^m Q_i - Q > \frac{1}{m} \sum_{i=1}^m Q_i \\ T_i^0, & \sum_{i=1}^m Q_i - Q \leq \frac{1}{m} \sum_{i=1}^m Q_i \end{cases}, \alpha > 1$$

Besides, in calculating the shortage cost, we count the times of shortages, noted by n_s .

Hence we get the fill rate:

$R_{fill} = \frac{\sum_{i=1}^m n_i - n_s}{\sum_{i=1}^m n_i}$ (10)

Therefore the first objective (the total cost) is the sum of Equation (1) to (9), and the rest objectives are Equation (8), (4) and (10) respectively.

3.3 GA Algorithm

We propose Genetic Algorithm (GA) approach to optimize the production inventory system total cost in supply chain. This study attempts to perform both performance analysis and optimization of various inventory policy settings. Genetic Algorithm is a class of evolutionary algorithms that utilize the theories of evolution and natural selection. GA begins with a population of randomly generated strings that represent the problems' possible solutions. Thereafter, each of these strings is evaluated to find its fitness. The initial population is subjected to genetic evolution to procreate the next generation of candidate solutions

- i. Initialization of population
- ii. Evaluation function
- iii. Selection
- iv. Crossover and mutation
- v. Repeat (ii) ~ (iv) until the termination criteria.

3.3.1 Initialization

The solution is coded as a chromosome simply in the form of (n, n_i, L_k) . Each element of the chromosome is a real number. For example, given the number of customer's $m = 3$, the two feasible solutions / chromosomes are shown below:

Chromosome 1:	(3, 2, 4, 5, 3.5, 4.0, 5.3)
Chromosome 2:	(2, 3, 2.5, 4.6, 3.7, 6.0)

Note that the length of different chromosomes might be different due to the value of n . In the example given above, the length of Chromosome 1 is 7, since $n = 3$ and thus there are 3 L_k 's. On the other hand, the length of Chromosome 2 is 6, since $n = 2$ and thus there are only 2 L_k 's. A group of chromosome

forms a population and in a population, a chromosome can also be called an individual. Given the population size N, we generate an initial population with size 2N.

3.3.2 Selection

This is the most important procedure, determining the performance of the algorithm. (Here a “better” could be more or less, depends on whether the objective function is to maximize or minimize.)

for each objective function m

sort $F_i = \{p^1, \dots, p^n\}$ based on the value of m and get $\{d^1, \dots, d^n\}$

set $d_{dis}^1 = \infty$ and $d_{dis}^n = \infty$

for k = 2 to (n - 1)

$$d_{dis}^k = d_{dis}^k + \frac{d^{k+1}(m) - d^{k-1}(m)}{m_{max} - m_{min}},$$

where $d^k(m)$ is the m function value of d^k , and m_{max} and m_{min} are the max and min value of m in this front.

Finally, all individuals in the 2N population are sorted first by front and then by crowding distance. Individual p is strictly better than q if and only if (i) $p_{rank} < q_{rank}$; or (ii)

$$p_{rank} = q_{rank} \text{ and } p_{dis} < q_{dis}.$$

Suppose the sorted population is $P = \{p^1, \dots, p^{2N}\}$ with p^1 be the best and p^{2N} be the worst, then the possibility of p^i be chosen is $i / [N(2N + 1)]$. Hence the better an individual is, the bigger chance it is chosen for the new population. Also an individual might be selected more than once or never. After N individuals have been selected, delete the rest un-chosen individuals.

3.3.3 Crossover and mutation

Crossover and mutation must be operated to make sure the off springs are still feasible. Crossover is taken between two random chromosomes with possibility P_c . Since the length of individuals is different and n determines the length of an individual, a crossover only takes place in $\{n_i\}_{i=1}^m$ so that it won't change the feasibility of a chromosome. Randomly select two individuals and randomly choose $a, b \in \{1, \dots, m\}$, where m is the number of customers. Suppose $a < b$ and then

exchange the subsequences $\{n_a, \dots, n_b\}$ between the two individuals. See the example below ($m = 3, a = 2, b = 3$).

Parent Chromosome 1:	(3, 2, 4, 5, 3.5, 4.0, 5.3)
Parent Chromosome 2:	(2, 3, 2.5, 4.6, 3.7, 6.0)
Offspring Chromosome 1:	(3, 2, 2.5, 4.6, 3.5, 4.0, 5.3)
Offspring Chromosome 2:	(2, 3, 4, 5, 3.7, 6.0)

Mutation is very similar to crossover expect that it takes place in one individual with possibility P_m . As long as n is fixed, the length of an individual does not change. Therefore randomly pick from $\{n_i\}_{i=1}^m$ and $\{L_k\}_{k=1}^n$ and put them with new random real values. See the example below ($m = 3$, pick n_2, L_1 and L_2).

Parent Chromosome:	(3, 2, 4, 5, 3.5, 4.0, 5.3)
Offspring Chromosome:	(3, 2, 3.7, 5.5, 2.9, 5.3)

4 ILLUSTRATIVE EXAMPLE

The input data refers to Srinivas and Rao (2010): $c = 1$ year; $P = 1600$ items per year for supplier; $D = 500$ items per year for retailer ($P / D = 3.2$); $s = 400$ \$ per setup for supplier; $s^1 = 100$ \$ per setup for retailer; $h_1 = 4$ \$ per item per year for supplier; $h_2 = 5$ \$ per item per year for retailer; $T = 100$ \$ per delivery batch from supplier to retailer; $T_i = \{30, 30, 30, 30\}$ \$ per delivery batch from retailer to customers; $D_i = \{120, 155, 90, 180, 55\}$ items per year for customers; $\sigma_i = \{5, 6, 3, 6, 3\}$; and lead time is calculated as Table 1.

TABLE 1
LEAD TIME ADDITIONAL COST

w	Lead time	(bw - aw)	cw	CL
1	7	0	0	0
2	5.25	1.75	0.4	0.7
3	3.5	1.75	1.2	2.8
4	2.625	0.875	5.0	7.175

The range of decision variables are: $15 \leq n \leq 24$; $10 \leq n_i \leq 39$; and $2.625 \leq L_k \leq 7$. Given $P_c = 0.75$, $P_m = 0.05$, the population size 175 and the termination criteria: to run 500 generations, the computational results are shown in Table 2. The total CPU time is only 4.753 seconds (CPU 2.66GHz, RAM 2.00GB, VC6.0).

5 CONCLUSIONS AND FUTURE SCOPE

We used to study the model with four objective variables such as, total cost, shortage cost, lead time cost. It is observed that for a given set of input values of Srinivas and Rao (2010), the developed model of mutual benefit strategy gives fill rate of above 84% and the supplier-retailer-customer total cost is more compare to consignment stock strategy of Srinivas and Rao (2010) wherein the model is for single vendor and five

buyers with single echelon where as our model is for single supplier – single retailer – five customers with two echelons. Future studies have to be made with multiple products and can be extended to multiple retailers.

REFERENCES

- [1] Aytug, H., Khouja, M. and Vergara, F.E. "Use of Genetic Algorithms to solve production and operations management problems: A Review", *Int. J of Prod. Research*, 41, pp.3955-4009, 2003
- [2] Ballou, R.H. *Business Logistics Management*, Prentice-Hal, Englewood Cliffs, New Jersey, 3rd ed., 1992.
- [3] Chaudhry, S.S. and Luo, W. "Applications of Genetic Algorithms in production and operations management: A Review", *Int. J of Prod. Research*, 43(19), pp.4083-4101, 2005.
- [4] Chidurala Srinivas and Rao, C.S.P. "Optimization of supply chains for single-vendor - multibuyer consignment stock policy with genetic algorithm", *Int. J of Adv. Manufacturing Technology*, 48(1/4), pp. 407-420, 2010.
- [5] Daniel, J.S.R. and Rajendran, C. "A simulation based Genetic Algorithm for inventory optimization in a serial supply chain", *Int. Tran. in Operations Research*, 12, pp.101-127, 2005.
- [6] Goyal, S.K, "Determination of optimum packing frequency of items jointly replenished", *Management Science*, 21, pp. 436-443, 1974.
- [7] Hans Siajadi, Rafaat N. Ibrahim, and Paul B Rochert "A Single-vendor multiple-buyer inventory model with a multiple-shipment policy" *Int. J of Adv. Manuf. Technology*, 27(9/10), pp. 1030-1037, 2006.
- [8] Houlihan, J.B., "International supply chain management", *Int. J of Phy. Distr. and Logi. Management*, 15, pp. 22-38, 1985.
- [9] Huayu Xu, Wenhui Fan, and Xu Xin, "Modeling and Algorithms on Vehicle Routing Problem with Dynamic Demands", *Proc. of INFORMS Int. Conf. on Service Science*, 6-8 August, 2009, Hong Kong.
- [10] Huayu Xu, Wenhui Fan, Tian Wei, and Lijun Yu, " An Or-opt NSGA-II Algorithm for Multi-Objective VRPTW", *IEEE Conf. on Aut. Sci. and Engineering*, August 23-26, 2008, Key Bridge Marriott, USA.
- [11] Pan, C.H.J, and Yang, J.S, "A study of an integrated inventory with controllable lead time", *Int. J of Prod. Research*, 40(5), pp. 1263-1273, 2002.
- [12] Prasun Das and Subhasis Chaudhury, "Optimization of supply chain inventory for multi retail and multi item class consumer product problems using genetic algorithm", *Int. J of Productivity and Quality Management*, 3 (1), pp. 33-73, 2008.
- [13] Simchi-Levi, Kaminsky, D, and Simchi-Levi, E., *Designing and Managing the Supply Chain: Concepts, Strategies, and Case Studies*. McGraw-Hill, New York, 2000.
- [14] Srinivas, Ch, and Rao, C.S.P., "Consignment stock policy with controllable lead time for effective inventory management in supply chains", *Int. J of Manuf. Technology and Management*, 10 (2/3), pp. 161-176, 2007.
- [15] Srinivas, Ch, Reddy, D.S, and Sarma, S.S.V.N, "GA approach to optimization of consignment stock policy based two echelons supply chain inventory model for single vendor – multi buyer", *Proc. of INFORMS Int. Conf. on Service Science*, 6-8th August, 2009, Hong Kong.