One-for-one Period Policy and a Series of Suppliers

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ABSTRACT

The purpose of this paper is to adopt and analyze a new ordering policy called one-for-one-period policy in a multi-echelon supply chain consisting of one retailer and a series of N suppliers. The main advantage of adopting the one-for-one-period $(1,T)$ ordering policy for retailers is the elimination of uncertainty for supplier which leads to total elimination of the safety stocks at all suppliers. This in turn leads to the reduction of the total system costs and in case any supplier's ordering cost is negligible it can even eliminate the need for him to carry any inventory**.** In addition to this advantage, the numerical results show that the application of this new policy for the retailer leads to the further advantage of outperforming the one-for-one $(S\text{-}1,S)$ policy in terms of total multi-echelon system cost under specified conditions. We derive the minimum total cost for this multi-echelon system and provide a numerical example to shed light on the merits of the proposed model compared to the common practice as reported in the literature.

Keywords: Inventory control, Supply chain, Multi-echelon, Cost reduction

1. INTRODUCTION

Supply chain management (SCM) is the term used to describe the management of materials and information across the entire supply chain, from suppliers to component producers to final assemblers to distributors. One of the major decisions in SCM is determination of inventory control policy. Axsater (1990) investigates a two-echelon inventory system in which the inventory policy of each echelon is $(S\text{-}1,\ S)$ and unsatisfied demand is backordered. Then, he (1993) formulates his previous model by applying $(r,\ Q)$ policy for each echelon. Matta and Sinha (1995) investigate a two-echelon inventory system consisting of a central warehouse and a number of retailers. Each retailer applies $(T,\ S)$ inventory policy with an identical review interval T and different maximum inventory level S. the central warehouse applies $(T,\ s,\ S)$ policy, where T is the same review interval as that of retailers; s is its reorder points, and S is its desired maximum inventory level. Axsater and Zhang (1999) consider a two-level inventory system with a central warehouse and a number of identical retailers. The warehouse uses a regular installation stock batch-ordering policy, but the retailers apply a different type of policy. When the sum of the retailers' inventory positions declines to a certain "joint" reorder point, the retailer with the lowest inventory position places a batch quantity order. Andersson and Melchiors (2001) propose an approximate method to evaluate inventory costs in a two-echelon inventory system with one warehouse and multiple retailers. All installations use $(S\text{-}1,\ S)$ policy. The retailers face Poisson demand and unsatisfied demands in the retailers are lost. Seo et al. (2002) develop an optimal reorder policy for a two-echelon distribution system with one central warehouse and multiple retailers. Each facility uses continuous review batch ordering policy. They propose a new type of policy to utilize the centralized stock information more effectively. They define the order risk policy, which decides the reorder time based on the order risk representing the relative cost increase due to an immediate order compared to a delayed one. Marklund (2002) introduces a new policy for inventory control in a two-level distribution system consisting of one warehouse and a number of non-identical retailers. The retailers use $(r,\ Q)$ policies, but the warehouse applies a new $(\alpha_0,\ Q_0)$ policy which leads to placing an order of Q_0 units as soon as a certain service level α_0 is reached. In his paper, a technique for exact evaluation of the expected inventory holding and backorder costs for the system is presented. Haji and Sajadifar (2008) considered an inventory system with information exchange consisting of one supplier and one retailer in which the retailer faces independent Poisson demand and applies continuous review (R,Q)-policy. The supplier starts with m initial batches (of size Q), and places an order to an outside source immediately after the retailer's inventory position reaches $R+s$, $(0 \le s \le Q-1)$. They obtain the exact value of the expected system costs.

Haji and Haji (2007) apply a new inventory policy, called one-for-one period or *(1, T)* ordering policy, which is different from the classical inventory policies used in the literature of inventory and production control systems. In this policy, an order for 1 unit of product constantly is placed at each fixed time period T. They propose this policy for a single echelon inventory system.

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In this paper, we apply the *(1, T)* policy to a multi-echelon supply chain system consisting of one retailer and a series of suppliers. We evaluate the total system cost which contains the holding and shortage costs at the retailer and the holding and ordering costs at the suppliers. By the numerical examples we compare the performance of the *(1, T)* policy with one-for-one policy in terms of total system cost.

2. THE MODEL

We consider a multi-echelon supply chain system consisting of one retailer and a series of N suppliers (Figure 1). In this system, we adopt a new policy recently introduced by Haji and Haji (2007) which is different from the classical inventory policies reported in the literature of inventory and production control systems. This new policy is to order 1 unit at each fixed time period T. They call this policy *(1,T)* or *one-for-one period ordering policy*. For stochastic demand, unlike any other policies used in practice and theory, in this policy both order size and order interval are fixed. By adopting this simple and very easy to apply policy for the retailer, the demand uncertainty for all echelons other than retailer's echelon will be eliminated. Briefly, in view of the fact that the demand is uncertain, by applying any classical inventory policy the orders which constitute the demands for all the upstream suppliers will have an uncertain nature. Hence, the uncertainty spreads into the supply chain and will be amplified in upstream echelons.

The new policy has several important advantages in multi-echelon supply chain such as:

Elimination of suppliers' safety stocks, decreasing retailer's safety stock due to elimination of the suppliers stock-out, and elimination of suppliers' shortage cost and information exchange cost due to a deterministic demand.

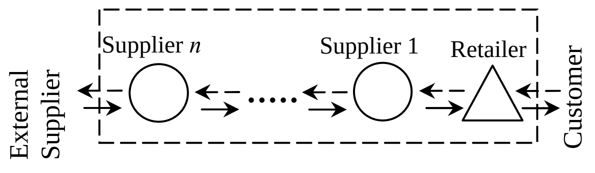

Figure 1. A multi-echelon supply chain

2.1 Assumption

- The retailer faces a Poisson demand.
- The retailer applies *(1, T)* policy.
- The suppliers use the continuous review policy.
- Unsatisfied demand by the retailer will be lost.
- The suppliers' ordering costs as well as the retailer's ordering cost are zero or negligible
- Shortage is not allowed at the suppliers.
- The transportation time for an order to arrive at a retailer from supplier 1 is constant.
- The transportation times between the suppliers are constant.
- The lead time for an order to arrive at supplier N is constant.

2.2 Notation

N: Number of suppliers.
λ: Demand intensity at retailer.
s: Cost of a lost sale at retailer.
h_r: Holding cost rate at retailer.
h_i: Holding cost rate at supplier i, i =1,2,…,N.
A_i: Ordering cost for supplier i, i =1,2,…,N.
T_r: Time interval between any two consecutive orders of the retailer.
Q_i: Order quantity of supplier i, i =1,2,…,N.
TC_r: Total cost at the retailer.
TC_i: Total cost at supplier i, i =1,2,…,N.
TSC: Total system cost

3. FORMULATION OF THE TOTAL SYSTEM COST

The total system cost contains the holding and shortage costs at the retailer and the holding and ordering cost at the suppliers. We have assumed that the retailer uses *(1, T)* policy hence the total cost at the retailer is (Haji and Haji, 2007):

$$TC_r = \frac{h_r}{T\lambda(1-x_0)} + s\lambda(1-\frac{1}{\lambda T}) \qquad (1)$$

Where $\frac{1}{T\lambda(1-x_0)} = I$ stands for the average inventory, $\lambda(1-\frac{1}{\lambda T}) = b$ represent the total lost sales per unit time, and x_0 satisfies the following equation:

$$x_0 = e^{-T\lambda(1-x_0)}$$

The total cost of the system is

$$TCS = \frac{h_r}{T\lambda(1-x_0)} + s(\lambda - \frac{1}{T}) + \sum_{i=1}^{N} TC_i$$

Since the ordering cost at the supplier i, i =1,2…N, is zero hence the one-for-one policy is the optimal policy for all the suppliers. The retailer's orders have deterministic time and quantity. Moreover, the transportation time to supplier 1 from the supplier 2 is constant, so that supplier 1 could plan the arrival of an order from the supplier 2 and deliver it to the retailer simultaneously. Thus, the supplier 1 does not need to carry any inventory, i.e. the total cost at the supplier 1 is zero. This analysis can be extended to all suppliers so the total cost for each supplier is zero. Thus the sum of total inventory cost of all the suppliers is equal to zero.

The above reasoning can be analytically introduced as follows:

The total cost at supplier 1 which contains the holding cost is (Hadley and whitin,1963):

$$TC_1 = \frac{h_1(Q_1 - 1)}{2} \qquad (2)$$

From cost function (2) one can conclude that optimal solution is Q_1=1 and the minimum TC_1 is zero. This conclusion can be extended to all suppliers. For example, to obtain TC_i the inventory cost for supplier i, we note that since the supplier i-1 orders 1 unit at each T units of time then the demand at supplier i is deterministic and is equal to 1 unit per T units of time. Thus, again, the total cost for supplier i is:

$$TC_i = \frac{h_i(Q_i - 1)}{2} \quad i = 2,\ldots,N \qquad (3)$$

The minimum total cost is zero and occurs when Q_i=1, i=2,…, N, hence, the total system cost includes just the holding and the shortage costs of the retailer.

$$TSC = TC_r = \frac{h_r}{T\lambda(1-x_0)} + s(\lambda - \frac{1}{T}) \qquad (4)$$

One can show that the above cost function is convex (Haji and Haji 2007).

4. NUMERICAL RESULTS

In this section we confine ourselves to a two-echelon supply chain consisting of one supplier and one retailer. We give a numerical example and compare the total system cost when the retailer uses (*1, T)* policy with the model proposed by Andersson and Melchiors (2001) for the case of one retailer in which both retailer and supplier use a one-for-one ordering policy.

To obtain the total system cost of one-for-one ordering policy we have used the method proposed by Andersson and Melchiors (2001). The parameters of the example are as follows:

N=1, λ=1, h_r=1, s=5, L_1=1, h_1=10, L_0=5

Where L_1 denotes the transportation time from the supplier to the retailer and L_0 represents the supplier's lead time.

We make sensitivity analysis for both methods by varying the values of the parameters, such as the transportation time from supplier to retailer, the rate of holding cost of retailer, and on the cost of a lost sale at the retailer.

Table 1 contains the results of sensitivity analysis on the transportation time from supplier to retailer. The total system cost with *(1,T)* policy is not sensitive to this parameter but the total system cost for the case of one-for-one policy depends on this parameter.

Table1. Sensitivity analysis on transportation time from supplier to retailer

L_1	*(S-1,S)* Policy	*(1,T)* policy
1	27.92	26.96
2	28.08	26.96
3	28.23	26.96
4	28.34	26.96
5	28.37	26.96
6	28.42	26.96
7	28.47	26.96
8	28.53	26.96
9	28.56	26.96
10	28.57	26.96

Figure 2 shows a comparison between the total system costs of both policies. From this figure, it is concluded that in this example for long transportation time the model proposed in this paper has a lower total system cost.

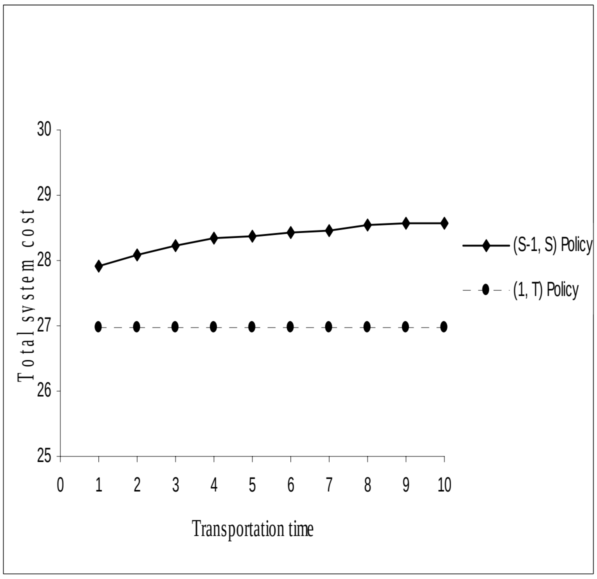

Figure 2. Sensitivity analysis on transportation time from supplier to retailer

Table 2 contains the results of sensitivity analysis on the rate of holding cost of retailer. Figure 3 shows a comparison between the total system costs of both policies. This figure indicates that when the rate of holding cost is less than 30 the total system cost of *(1, T)* policy is lower than the total system cost of one-for-one policy.

Table2. Sensitivity analysis on rate of holding cost of retailer

h_r	*(S-1,S)* Policy	*(1,T)* policy
25	29.51	28.82
26	29.64	29.12
27	29.73	29.37
28	29.82	29.63
29	29.91	29.84
30	30.00	30.00
31	30.09	30.10
32	30.18	30.20
33	30.27	30.29
34	30.36	30.39
35	30.46	30.49

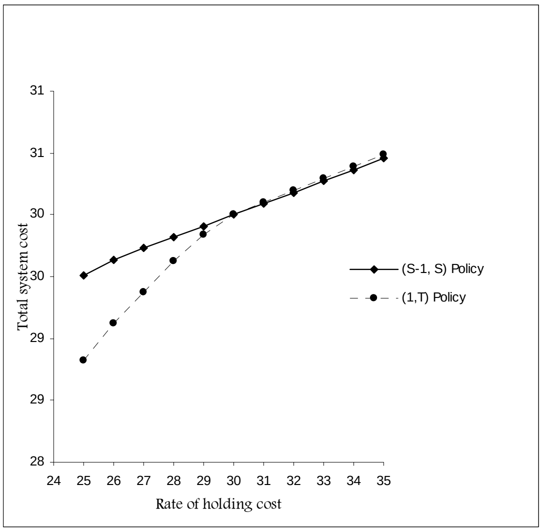

Figure 3. Sensitivity analysis on rate of holding cost of retailer

The results of sensitivity analysis on the cost of a lost sale at retailer are represented in table 3. Figure 4 indicates that when the cost of a lost sale is more than 20, *(1, T)* policy amounts to a lower total system cost.

Table3. Sensitivity analysis on cost of a lost sale at retailer

s	*(S-1,S)* Policy	*(1,T)* Policy
15	15.45	15.49
16	16.36	16.39
17	17.27	17.29
18	18.18	18.20
19	19.10	19.10
20	20.00	20.00
21	20.90	20.83
22	21.82	21.60
23	22.73	22.34
24	23.61	23.06
25	24.43	23.75

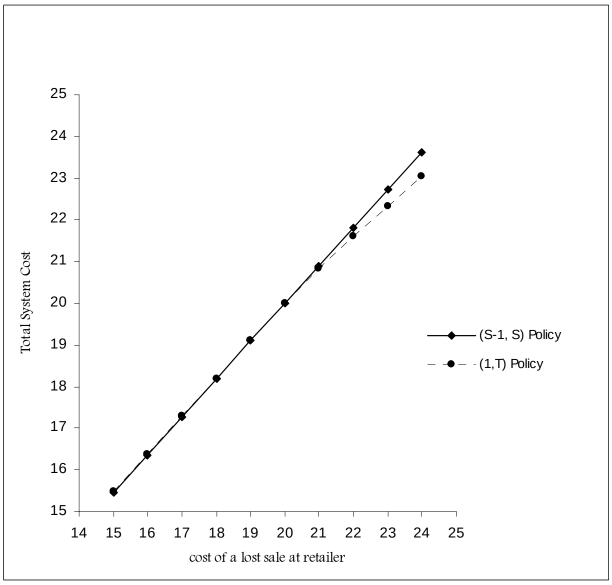

Figure 4. Sensitivity analysis on cost of a lost sale at retailer

4. CONCLUSIONS

In this paper we adopted the *(1, T)* policy and analyzed its application in a multi-echelon supply chain. The most important advantage of this policy is that the suppliers are facing a uniform and deterministic demand which is originated by the retailer. This advantage facilitates the inventory planning and leads to elimination of holing inventory at the suppliers. We provided a numerical example, which shows under some conditions the *(1, T)* policy outperforms the one-for-one policy in terms of the total system cost.

REFERENCES

[1] Andersson, J., Melchiors, Ph. "A two-echelon inventory model with lost sales", *International Journal of Production Economics*, Vol. 69, pp307-315, 2001

[2] Axsater, S. "simple solution procedures for a class of two-echelon inventory problem", *Operations Research*, Vol. 38, pp64-69, 1990

[3] Axsater, S. "Exact and approximate evaluation of batch-ordering policies for two-level inventory systems", *Operations .Research*, Vol. 41, pp777-785, 1993

[4] Axsater, S., Zhang, W.F. "A joint replenishment policy for multi-echelon inventory control", *International Journal of Production Economics*, Vol. 59, pp. 243-250, 1999

[5] Hadley,G., Whitin, T, M, “Analysis of Inventory Systems”, Prentice-Hall, Englewood Cliff, N. J., 1963

[6] Haji, R., Haji, A. "Introducing One-for-one Period ordering Policy and its optimal solution based on Queueing Theory", *Journal of Industrial and*

Systems Engineering, Vol. 1, pp200-217, 2007
[7] Haji, R., Sajadifar, S. M., "Deriving the exact cost function for a two-level inventory system with information sharing", *Journal of Industrial and Systems Engineering*, Vol. 2, pp41-50, 2008
[8] Marklund, J. "Centralized inventory control in a two-level distribution system with Poisson demand", *Naval Research Logistics*, Vol. 49, pp798-822, 2002
[9] Matta, K.F., Sinha, D. "Policy and cost approximations of two-echelon distribution systems with a procurement cost at the higher echelon", *IIE Transactions*, Vol. 27, pp. 638-645, 1995
[10] Seo, Y., Jung, S., Hahm, J., "Optimal reorder decision utilizing centralized stock information in a two-echelon distribution system", *Computers & Operations Research*, Vol. 29, pp171-193, 2002