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AN INTEGRATED VENDOR - BUYER INVENTORY MODEL WITH REWORKING OF IMPERFECT PRODUCTION ITEMS AND SHORTAGE BACKORDERING

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ABSTRACT

In this paper we develop an integrated vendor-buyer inventory model with imperfect production process. Usually the vendor apply the inspection process for finding the imperfect quality items and selling the imperfect items at a discounted price to a secondary market. Here we develop an inventory model under the concept of reworking the defective items. Mathematical model and numerical examples is provided for the proposed model.

Keywords- *Integrated inventory model. imperfect items, rework, backordering, inventory coordination.*

I. INTRODUCTION

Supply chain management has been considered the most popular operations strategy for improving a firm competitiveness. Cao and Zhang [1], demonstrated that firms have been attempting to achieve greater collaborative advantages with their supply chain partners in the past few decades and that supply chain collaborative advantages have a bottom line influence on firm performance. Goyal [2] considered the joint optimization problem of a single vendor and single buyer, in which he assumed that the vendor's production rate is infinite. Banerjee [3] assumed finite rate of production and developed a joint economic lot-size model for the product with a lot-for-lot shipment policy. Goyal [4] developed an integrated vendor-buyer inventory model in which each production batch was shipped to the buyer in smaller lot of equal size. Lu [5] considered the integrated inventory model with the objective of minimizing the vendor's total cost subject to the maximum costs which the buyers were prepared to incur. Hill [6] illustrated that in general neither of the two policies described in Lu [5] would be optimal. Viswanathan [7] presented the results of a detailed numerical study that analysed the relative performance of the two different strategies of equally and unequally sized batch shipments as described in Lu [5] model.

The rest of the paper is organized as follows. Section 2, provided the notation and assumption of proposed model. Section 3, we develop a mathematical model. Section 4, provides a numerical example and finally we conclude the paper in Section 5

II. NOTATIONS & ASSUMPTIONS

We consider a simple supply chain problem with a single vendor and single buyer. The buyer has an annual demand rate of D units for the given product and places regular orders of fixed size Qp. The vendor prepares for the repeating flow of orders of size Qp from the buyer by producing items in batches of size Qp and planning to have each batch delivered to the buyer in n shipments, each with a lot of Q units. The vendor fulfills the shipment of Q units with a known and fixed lead time. Since the production process is not perfect, some of the items produced may be defective. Therefore, we assume that once an item is produced, it is inspected. The inspection time is negligible in comparison to the time needed to produce an item. The vendor satisfies the buyer's demand.

Hill [8] determined the optimal production and inventory policy for a vendor manufacturing to supply to a single buyer. Goyal and Nebebe [9] considered the problem of determining economic production and the shipment policy of a product supplied by a vendor to a buyer. Wu and Ouyang [10] considered the integrated single vendor – single buyer inventory system with shortage. Chang et al [11] studied the lead time and ordering cost reduction problem in the single vendor single buyer integrated inventory model. Chung [12] showed that Wu and Ouyang's [10] proof of a global cost minimum was incomplete. Salameh and Jaber [13] developed an economic order quantity model where a random proportion of the items in lot are defective. Khan et al [14] extended the work of Salameh and Jaber [13] and used the approach of assuming that the inspection process was not error free and the type I and type II inspection errors follow a known probability density function.

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The purpose of this paper is to develop an integrated vendor buyer inventory model with rework of defective items and shortage backordering with good quality items. Since all customers are assumed to be willing to wait for a latter shipment at some known cost, shortages at the buyer are allowed and are completely backordered. The following assumptions and notations are used in this model.

Notations

Q_p : The size of a production batch of good quality items at the vendor.

Q : The size of the shipments from the vendor to the buyer.

B : The maximum backorder quantity in units at the buyer.

n : The number of shipments per batch production run, a positive integer ($Q_p = nQ$)

D : The annual demand of the buyer

P : The annual production rate ($P > D$) at the vendor

S_v : The setup cost per production run for the vendor

S_B : The ordering cost per order for the buyer

γ : The probability that an item produced is defective

$f(\gamma)$: The probability density function of γ

C_i : The vendor's inspection cost per unit

C_d : The vendor's cost of producing a defective item

b : The backordering cost per unit per year at the buyer

h_r : The holding cost per unit per year for the vendor

h_B : The holding cost per unit/per year for the buyer

F : Fixed transportation cost per shipment from the vendor to the buyer

T : Time interval between successive shipments of Q units

T_c : Cycle Time = $T_1 + T_2 = nT$

T_1 : Period during which the vendor produces

T_2 : Period during which the vendor supplies from inventory

C_R : The rework cost per unit (\$/unit)

C_S : The disposal cost per unit (\$/unit)

θ_1 : The portion of scrap items produced during reworking defective items

β' : Social cost from vehicle emission (mu/h)

v : average velocity (km/h)

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d : distance travelled (from supplier to buyer km)

Assumptions

1. The demand rate is known, constant and continuous.
2. The lead time is known and constant.
3. The production processes are imperfect and may produce defective items. The defective percentage γ has a probability density function $f(\gamma)$. To ensure that the vendor has enough production capacity to produce the buyer's annual demand, it is assumed that $\gamma < 1 - D/p$.
4. Once an item is produced, it is inspected with an inspection cost of C_i. A defective items incurs a cost of C_d from the vendor. C_d is the difference between regular and reduced selling prices.
5. Shortages are completely backordered.
6. A single product is considered.
7. There is a single vendor and a single buyer.

III. MATHEMATICAL MODEL

The total cost of an integrated vendor buyer model is defined as follows :

$TC_c(n, Q, B)$

$$= S_v + S_B + nF + (C_i + C_d\gamma)\frac{nQ}{(1-\gamma)} + h_v\left\{\frac{nQ^2}{p(1-\gamma)}\left(1-\frac{n}{2}\right) + \frac{n(n\text{-}1)Q^2}{2D} + \frac{n^2Q^2\gamma^2}{2p(1-\gamma)^2}\right\}$$

$$+\frac{h_B}{2}\frac{n(Q-B)^2}{D} + \frac{nb}{2}\frac{B^2}{D} + C_r[\gamma nQ] + C_S[\gamma nQ\theta_1] + 2\beta'\frac{d}{v} \qquad \ldots (1)$$

Since the replenishment cycle length $T_C = \dfrac{nQ^2}{D}$, the expected total annual cost of an integrated vendor, buyer model is as follows :

$$ETC(n, Q, B) = \frac{E\left[TC_c(n, Q, B)\right]}{T_c}$$

$$= \frac{\left(S_v + S_B + \dfrac{2\beta' d}{v} + nF\right)D}{nQ} + C_iDE\left[\frac{1}{1-\gamma}\right] + C_dDE\left[\frac{\gamma}{1-\gamma}\right]$$

$$+ h_v\left\{\frac{QD}{p}\left(1-\frac{n}{2}\right)E\left[\frac{1}{1-\gamma}\right] + \frac{(n\text{-}1)Q}{2} + \frac{nQD}{2P}E\left[\frac{\gamma}{(1-\gamma)^2}\right]\right\}$$

$$+ \frac{h_B}{2}\frac{(Q-B)^2}{Q} + \frac{bB^2}{2Q} + C_RE[\gamma]D + C_SE[\gamma]\theta_1D \qquad \ldots (2)$$

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where E[γ] denotes the expected value of γ.

Taking the first derivative of ETC(n,Q,B) with respect to Q and B, we have

$$Q^* = \sqrt{\frac{2\left(S_v + S_B + \frac{2\beta' d}{v} + nF\right)D}{n\left\{h_v\left\{\frac{D}{p}(2-n)E\left[\frac{1}{1-\gamma}\right] + (n\text{-}1) + \frac{nD}{P}E\left[\frac{\gamma}{(1-\gamma)^2}\right]\right\} + \frac{h_B}{(h_B+b)}\right\}}} \quad \ldots (3)$$

$$B^* = \frac{h_B}{(h_B+b)}Q^*$$

IV. NUMERICAL EXAMPLE

Consider an integrated vendor-buyer cooperative production – inventory system with following parameters.

P = 160,000, D = 50,000, S_v = 300, S_B = 100, F = 25, n = 6, h_v = 2, h_B = 5, C_i = 0.5, b = 10, C_d = 10.3, C_R = 5, C_S = 2, θ_1 = 0.1, β′ = 0.5, d = 250, v = 180.

Using the above parameters the optimal order quantity Q^* = 753 backorder quantity, B^* = 250 and the expected annual cost is ETC(n, Q, B) = $18280.

V. CONCLUSION

In this paper we analysed an integrated inventory model with reworking of defective items. Based on the numerical result, we could finalise that the reworking of defective items is better than the selling of defective items at a discount price in a secondary market.

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