

Manufacturing System with Discrete Random Demand under Two Level of Trade Credit Finance

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(Received January 12, 2022)

Abstract: The primary aim of this article is to analyze a manufacturing system under bi-level trade credit policy. The production rate is fixed finite per unit time and demand rate of items is discrete stochastic. In this trade credit policy, a supplier gives a delay period in payment to the retailer and retailer uses similar extension in credit policy to their client. We formulate the retailer's scheduling policy by optimization the cost of the inventory system. With the help of numerical examples, the system's optimal replenishment policy may be easily verified.

Keywords: Manufacturing System, Trade Credit, Stochastic Demand.

1. Introduction

The traditional Economic Manufacturing Quantity (EMQ) model is beneficial to take optimal decision policy in inventory control problems Hadley¹. One of the basic assumptions of the EMQ model is an immediate payment of received items by the buyer is unrealistic in day-to-day dealing. Delay in payment policy usually occurs in the real market Goyal². The supplier of items offers a certain fixed period to the buyer to settle down his account Hadley¹, Agarwal³. This period is free from any interest is called a credit period Aggarwal³, Chang et.al⁴, Chung et.al.⁵. The credit period policy impresses both buyer and supplier. It indirectly reduces the purchase cost and gives some economic advantages to the buyer to earn interest to the revenue realized during this period Shinn et.al⁶, Chang⁷, Jamal et.al.⁸ Mahata⁹. This policy motivates buyers to increase their order quantities and attracts a new client who thinks this delay period is a price discount Chang⁷, Kreg et.al¹⁰. The credit policy also plays a vital role in promoting the commodities of suppliers Goswami et.al¹¹. By offering a credit period, the supplier expects more profit from the increased sale volume and compensates for the revenue

loss incurred by providing this policy Shinn⁶. Trade credit offers a long-term opportunity to work with the supplier and buyer to optimize their mutual profit Huang¹². The supplier would charge high interest on the unpaid amount if the account did not settle within the credit period.

During the past four decades, much-existing literature has explored the potential benefit of delay in payment policy. It has become one of the most important and attractive research fields. The concept of credit period policy to the inventory system first introduced by Goyal². He developed a mathematical model and evaluated the revenue earned during credit period on the sold items. Chand and Ward¹³ assessed the optimal order quantity formula for the delay in payment policy, assuming that the cost of funds tied up in inventory is as consistent as in the classical EOQ model. Later on, Aggarwal and Jaggi³ developed a deterioration inventory model under trade credit finance by assuming the exponential rate of item deterioration. Shinn et al.⁶ developed a trade credit inventory model by adding quantity discounts for freight costs. Chung and Huang¹⁴ extended the model proposed by Goyal's² for finite replenishment rate and developed a trade credit inventory system. Chung and Huang¹⁵ determined the retailer's scheduling plan under trade credit financing for deteriorating items with fixed storage capacity.

All the above literature assumed that one level trade credit finance offered by the supplier to the retailer for the payment. However, they have not considered a similar trade credit policy offered by retailers to the consumer. This assumption is infeasible, especially in supply chain scenarios; for example automobile companies can delay paying spare part provider vendors. They also offer a similar delay period to the showroom dealer to enhance their product demand. Huang¹⁶ extended Goyal's² model with the assumption that retailers will also use the same trade credit policy to the customer to promote market competition, that two-level trade credit policy and this delay in payment policy reflected as a realistic situation of the market. Huang¹⁷ extended the work of Huang¹⁶ for a fixed, satisfactory production rate. Huang and Hus¹⁸ developed a partial trade credit inventory model. They proposed that the retailer will not pay any amount at received items but customer have to pay a partial amount of cost to the retailer at the time of receiving the items and remaining amount he can pay at the end of credit period. Goswami et al.¹¹ developed a deterioration economic production quantity model under a two-level of trade credit finance. J. Wu et al.¹⁹ analyzed a lot size deteriorating inventory model with expiry date and evaluate optimal credit period. Bhuni et al.²⁰ developed a delay policy for two separate warehouses having different preserving facilities. Otrodi et al.²¹ discussed a two-level

trade credit model for multiple demand classes. Zou and Tian²² a two-level trade credit model with a flexible two-part trade credit policy.

All the inventory systems quoted above are deterministic character. Shah and Shah²³ established a probabilistic model with a delay in payment is policy.. Shah and Shah²⁴ analyzed a discrete in time probabilistic inventory model for deteriorating items under the trade credit finance. De and Goswami²⁵ optimize the joint relevant cost for the customer and retailer and find their respective prices. The demand for items was determined or continuous stochastic in the above-mentioned probabilistic inventory models under trade credit finance. Scenario demand may be discrete and stochastic in nature of the actual market. Some items are used only in discrete batch size shape, for example, computer chip, chemical product, printer cartridge, blood-bottle, computer spare parts, medicine, cement, liquid drinks etc, is in specific size or lot or bottle size or packet. Therefore, the character of the items demand is also of discrete type. Customer demand and their arrival to the shop are independent to each other. The behaviour of such type demand can be accurately approximate by discrete probability distribution. Federguren and zipking²⁶, Halmay et al²⁸, Tan and Wang²⁷, O. Prakash et al.²⁹, Roger³⁰ and other researchers also studied the inventory model with discrete demand. Therefore, in the present paper, a mathematical model is developed for discrete stochastic demand with two levels of trade credit finance. This study has been taken two types of trade credit policy according to the relation between supplier to retailer and retailer to his customer. The optimal decision policy depends on the joint inventory cost of the supplier and retailer. This model illustrates with the help of numerical examples.

2. Assumptions and Notations of the Model

The mathematical model in this article is developed on the basis of the following assumptions and notations.

1. Production rate p is constant and grater than maximum demand.
2. X : non-negative discrete random variable denoting demand of items with probability mass function $px(.)$, a minimum value $a = \min_x \{x | px(x) > 0\}$, maximum value $b = \max_x \{x | px(x) > 0\}$ and mean demand μ .
3. Holding cost of storing inventory refers to the amount of time that an item has spend in the retailer's store at the beginning of i^{th} to the end of i^{th} period and holding cost is calculated at the end of i^{th} period.
4. Discrete times units i , $i=0,1,2,...,n$, n is production cycle in years.
5. l_1 : Retailer's trade credit period offered by the supplier in years.

6. l_2 : Customer's trade credit period offered by the retailer in years.
7. Payment for a received order is made at the end of the credit period. Credit period is a multiple of the length of review period. No interest is earned in the last review period of credit period.
8. When $i \geq l_1$, the account is settled at time $i = l_1$ and the manufacturer starts paying the interest charges on the item in the stock at the rate of U_c .
9. When $i \leq l_1$ the account is settled at time $i = l_1$ and the manufacturer need not pay any interest charges.
10. The retailer can earn revenue during l_2 to l_1 period with the interest rate ϕ_e .
11. x_{min} = minimum demand, x_{max} = maximum demand.
12. $l_1 \geq l_2, \phi_c \geq \phi_e$.
13. The costs in the model are as follows:
 - c = The purchasing price of raw material per item (\$/unit)
 - c_0 = The setup cost per production cycle (\$/order).
 - c_h = The holding cost per item per unit time (\$/unit/unit time).
 - h_c = Unit stock holding cost per item per year excluding interest charges.
 - γ_c : Unit purchasing price.
 - γ_s : Unit selling price, where $\gamma_s \geq \gamma_c$.
 - ϕ_e : Interest which can be earned per \$ per year (\$/\$/unit).
 - ϕ_c : Interest charged per \$ in stock per year by the supplier (\$/\$/unit).
 - $C(n)$ = The expected total annual production cost.

3. Mathematical Model

Production process starts at time $t = 0$ and continue up to the target value $t = n_0$. The inventory of product reaches a maximum level at n_0 and then it consumes to complete the retailer's demand and come to zero at the end of production cycle n . The inventory level $I(i)$, at time i is describe during production and consumption period by following relation. During production period $(0, n_0)$, $I_1(i) = (p - x)i$ for $i = 0, 1, 2, \dots, n_0$ with initial condition $I(0) = 0$. During consumption period $(n_0 + 1; n)$, $I_2(i) = n_0 p - x_i$, for $i = n_0 + 1, n_0 + 2, \dots, n$ with ending condition $I(n) = 0$ when x is maximum, since shortages are not allowed in model.

The expected annual total relevant cost function for the retailer's consists the following component.

1. Expected annual ordering cost $A_0 = \frac{c_0}{n}$.
2. Expected annual stock holding cost H_c is

$$H_c = \frac{h_c}{n} \left[\sum_{x_{\min}}^{x_{\max}} \sum_{i < n_0} (p - x) i p x(x) + \sum_{x_{\min}}^{x_{\max}} \sum_{i > n_0+1} (n_0 p - x i) p x(x) \right]$$

$$= \frac{h_c}{6p^2} [p^2(3n^2 + n + 1)(b - \mu) + n^2(p^2\mu - b^3)]$$

3. As per the assumption of offer trade credit periods and account settlement policy, there are four different cases (1) $l_1 \leq n_0$, (2) $l_2 \leq n_0 \leq l_1 \leq n$ (3) $n_0 \leq l_2 \leq n \leq l_1$ and (4) $n \leq l_2$ may arise to derive the capital opportunity cost as follows.

Case-1 ($l_1 \leq n_0$): expected annual interest payable P_{c1} is

$$P_{c1} = \frac{\gamma_c \phi_c}{n} \left[\sum_{x_{\min}}^{x_{\max}} \sum_{i=l_1+1}^{n_0} I_1(i) i p x(x) + \sum_{x_{\min}}^{x_{\max}} \sum_{i=n_0+1}^{\infty} I_2(i) i p x(x) \right]$$

$$= \frac{\gamma_c \phi_c}{6p^2} \left[p^2(3n^2 + n + 1)(b - \mu) + n^2(p^2\mu - b^3) - (3l_1^2 + l_1 + 1)p^2(p - \mu) \frac{l_1}{n} \right]$$

Case-2 ($l_2 \leq n_0 \leq l_1 \leq n$): expected annual interest payable P_{c2} is

$$P_{c2} = \frac{\gamma_c \phi_c}{n} \left[\sum_{x_{\min}}^{x_{\max}} \sum_{i=l_1+1}^N I_2(i) i p x(x) \right]$$

$$= \frac{\gamma_c \phi_c}{6n} [n(n+1)(3bn - \mu(2n+1) + l_1(l_1+1)(-3bn + \mu(2l_1+1)))]$$

Case-3 ($n_0 \leq l_2 \leq n \leq l_1$): expected annual interest payable P_{c3} is zero since retailer will not pay any interest in this case as account is settled within credit period.

Case-4 ($n_0 \leq l_2$): Similar as case 3 retailer will not pay any interest in this case, therefore, expected annual interest payable $P_{c4} = 0$.

4. According to assumption (10), there are four cases to occur in interest earned per year.

Case-1 ($l_1 \leq n_0$): expected annual interest earned E_{c1} is

$$E_{c1} = \frac{\gamma_s \phi_e}{n} \sum_{x_{\min}}^{x_{\max}} \sum_{i=l_2+1}^{l_1} x i p x(x)$$

$$= \frac{\gamma_s \phi_e \mu (l_1 + l_2)}{2n} \{(l_1 + 1) - l_2\}$$

Case-2 ($l_2 \leq n_0 \leq l_1 \leq n$): expected annual interest earned E_{c2} is

$$\begin{aligned} E_{c2} &= \frac{\gamma_s \phi_e}{n} \sum_{x_{\min}}^{x_{\max}} \sum_{i=l_2+1}^{l_1} x i p x(x) \\ &= \frac{\gamma_s \phi_e \mu (l_1 + l_2)}{2n} \{(1 + l_1) - l_2\} \end{aligned}$$

Case-3 ($n_0 \leq l_2 \leq n \leq l_1$): expected annual interest earned E_{c3} is

$$\begin{aligned} E_{c2} &= \frac{\gamma_s \phi_e}{n} \sum_{x_{\min}}^{x_{\max}} \sum_{i=l_2}^n x i p x(x) + \sum_{x_{\min}}^{x_{\max}} (l_1 - n) n x p x(x) \\ &= \frac{\gamma_c \phi_c \mu}{2n} \{n(n-1) + 2(l_1 + l_2 - l_2^2)\} \end{aligned}$$

Case-4 ($n \leq l_2$): expected annual interest earned E_{c4} is

$$\begin{aligned} E_{c4} &= \frac{\gamma_s \phi_e}{n} \sum_{x_{\min}}^{x_{\max}} (l_1 - l_2) n x p x(x) \\ &= \gamma_c \phi_c (l_1 - l_2) \mu \end{aligned}$$

From the above arguments, the expected annual total relevant cost for the retailer can be explicitly expressed as $C(n)$ = Ordering cost + stock-holding cost + interest charged - interest earned. Thus

$$(1) \quad C(n) = \begin{cases} C_1(n); & \text{if } l_1 \leq n_0 \\ C_2(n); & \text{if } l_1 \leq n_0 \leq l_1 \leq n \\ C_3(n); & \text{if } n_0 \leq l_2 \leq n \leq l_1 \\ C_4(n); & \text{if } n \leq l_2 \end{cases}$$

where

$$(2) \quad \begin{aligned} C_1(n) &= \frac{c_0}{n} + \frac{h_c + \gamma_c \phi_c}{6p^2} \{p^2(3n^2 + n + 1)(b - \mu) + n^2(p^2\mu - b^3)\} \\ &\quad - \frac{\gamma_c \phi_c (p - \mu) l_1}{6n} (3l_1^2 + l_1 + 1) - \frac{\gamma_s \phi_e (l_1 + l_2)}{2n} \{(l_1 + 1) - l_2\} \end{aligned}$$

$$(3) \quad \begin{aligned} C_2(n) &= \frac{c_0}{n} + \frac{h_c}{6p^2} \{p^2(3n^2 + n + 1)(b - \mu) + n^2(p^2\mu - b^3)\} \\ &\quad + \frac{\gamma_c \phi_c}{6n} (n(n+1)(3bn - \mu(2n+1)) \\ &\quad + l_1(l_1+1)(-3bn + \mu(2l_1+1))) - \frac{\gamma_s \phi_e (l_1 + l_2)}{2n} \{(1 + l_1) - l_2\} \end{aligned}$$

$$(4) \quad \begin{aligned} C_3(n) &= \frac{c_0}{n} + \frac{h_c}{6p^2} \{p^2(3n^2 + n + 1)(b - \mu) + n^2(p^2\mu - b^3)\} \\ &\quad - \frac{\gamma_c \phi_c \mu}{2n} \{n(n-1) + 2(l_1 + l_2 - l_2^2)\} \end{aligned}$$

$$(5) \quad C_4(n) = \frac{c_0}{n} + \frac{h_c}{6p^2} \{p^2(3n^2 + n + 1)(b - \mu) + n^2(p^2\mu - b^3)\} - \gamma_c \phi_c \mu (l_1 - l_2)$$

3.1 Computational Procedure

Since n must be a non-negative integer, necessary condition for $C(n)$ to be a maximize at n^* is

$$(6) \quad \Delta C(n^* - 1) \geq 0 \geq \Delta C(n^*)$$

where $\Delta C(n) = TC(n + 1) - TC(n)$. We have consider $b = lrn$ and $\mu = rn$ for numerical calculation. The computational procedure is explained with the help of numerical examples in section 4.

4. Numerical Examples and Sensitivity Analysis

We consider the values of different parameters as follows $p = 400$ unit/unit time, $r = 30$, $c_0 = \$500/\text{order}$, $l = 2$, $\varphi_c = \$0.0025/\text{\$/unit time}$, $\varphi_e = \$0.0005/\text{\$/unit time}$, $\gamma_s = \$6/\text{unit}$, $\gamma_c = \$5/\text{unit}$, and $h_c = \$3/\text{unit/unit time}$. With the help of Mathematica 7 software, we obtain the optimal value of production cycle n^* and corresponding optimal production cost $C(n^*)$ of system.

Table I. Optimal Production Cycle

Case 1 :									
l_1	l_2	$C_1(n)$	3112.23	6727.93	1075.060	1438.190	1631.050	14638.707	6803.85
4	2	n	4	5	6	7	8		10
Case 2 : $l_1 = 6, l_2 = 4$									
$C_2(n)$	3103.5.50	4207.0.79	5353.5.19	6455.3.05	7401.2.5	8054.5.84	8250.9.82	77965.92	6466.0.71
n	10	11	12	13	14	15	16	17	18
Case 3 :									
l_1	l_2	$C_3(n)$	515.80	818.03	1252.42	1715.87	2008.80	1814.23	677.71
8	6	n	3	4	5	6	7	8	9
Case 4 :									
l_1	l_2	$C_4(n)$	458.03	1072.42	1805.87	2458.80	2714.23	2117.71	575.10
9	7	n	4	5	6	7	8	9	10

From Table I it is observed that $C_1(n)$, $C_2(n)$, $C_3(n)$ and $C_4(n)$ attain their maximum value at $n = 8$, $n = 16$, $n = 7$ and $n = 8$, respectively. Hence, the optimal production cycle for case 1, case 2, case 3 and case 4 are $n^* = 8$, $n^* = 16$, $n^* = 8$ and $n^* = 7$, respectively. It is also observed that case 3 and case 4 are more economically beneficial than case 1 and case 2.

Table II: Dependence of the optimal production policy on the parameters p , r and c_0

$r = 30, c_0 = 200$			$r = 25, c_0 = 200$		$r = 30, c_0 = 250$	
p	n^*	$C(n^*)$	n^*	$C(n^*)$	n^*	$C(n^*)$
300	6	7060.21	7	10010.30	6	7068.55
350	7	11195.80	9	15556.30	7	11203.00
400	8	16580.50	9	22694.10	8	16587.0
450	9	23377.67	9	27566.20	9	23383.10
500	9	294155.80	9	31031.602	9	29421.30

- The optimal production cycle n^* and $C(n^*)$ both increases as the values of production rate increases this propose that retailer will order less quantity since production rate is higher.
- The optimal production cycle n^* decreases and $C(n^*)$ increases as the value of R increases, that is, the average demand increases. This implies that retailer will order more quantity to earn more money in less time period.
- The optimal time n^* and $C(n)$ both increases as the value of set up cost c_0 increases which implies that retailer will order more quantity to take benefit of only one setup cost.

Table III: Variation in $C(n^*)$ and n^* with respect to cost parameters γ_s and γ_c

γ_s	N^*	$C(N^*)$	γ_c	N^*	$C(N^*)$
8	8	16040.5	6.0	8	22793.8
7	8	16175.5	5.5	8	21172.8
6	8	16310.5	5.0	8	19552.0
5	8	16445.5	4.5	8	17931.2
4	8	16580.5	4.0	8	16310.5

From the above table it is observed that γ_c is more sensitive on optimal cost of system than γ_s .

5. Conclusion

This article discusses a manufacturing system for discrete stochastic demand under allowable delay in payment. The study differs from a large set of literature introducing the concept of discrete stochastic demand with mean and maximum value as a function of the product cycle. It is suitable for seasonal products with varying seasons. Further, this study takes into account the credit policy adopted by both retailers as well as wholesalers. Table I, Table II, and Table III describe the effects of changing the values of various

parameters on the optimum cycle time N^* and cost $C(N^*)$. The scope of the study can be analyzed by including more realistic features like deteriorating items, space capacity, different delay policies, and trade credit-dependent cost function.

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